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INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kĭl'o
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	ăt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb.
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

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RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 11, Number 11, November 1970

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the Bureau of Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the Bureau of Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

Department of Defense
Department of the Interior
Department of Agriculture
Department of Commerce
Department of Health, Education, and Welfare
Atomic Energy Commission

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service
Bureau of Radiological Health

Reports

Analysis of Iodine-131 Data in Bovine Thyroids, October 1964 Through February 1969

John L. Russell and *Gerald A. Pliner*[1]

A detailed analysis of the bovine thyroid data from October 1964 through February 1969, as reported in *Radiological Health Data and Reports*, shows that most positive results can be related to various nuclear tests with known atmospheric intrusions. The widespread nature of various samples having positive concentrations of short-lived fission products and the rapid increase of levels in these samples indicate the source to be a major atmospheric intrusion.

Estimates determining thyroid dose in man from iodine-131 concentrations in bovine thyroids appear to be feasible under selected conditions but are of little use in evaluating nationwide network data. The lower limit of detectability is 1 pCi ^{131}I/g bovine thyroid, and most samples at this level have a 2-standard deviation error greater than the measured quantity.

The Bureau of Radiological Health (BRH), Environmental Health Service, has operated a national program for the collection and analysis of iodine-131 in bovine thyroids since October 1964. This program, known as the Bovine Thyroid Network, has been described in *Radiological Health Data and Reports* (*RHD&R*) (*1*). The program was based on pilot studies by the BRH (*2–3*) and on the work performed by other investigators. Data from the network was routinely published in the above reference. Because levels of radioactivity detected in this network were very low, the project was discontinued on March 1, 1969.

A review of the bovine thyroid data through 1965 was presented by Baratta (*4*). Since this review, a number of atmospheric nuclear tests have been conducted providing additional information for the evaluation of bovine thyroids as an environmental sampling tool. This paper attempts to evaluate the data for the period that the Bovine Thyroid Network was a routine operational program.

Data evaluation

Several factors contribute to the concentrations of iodine-131 in bovine thyroids and to the relative percent of thyroids having measurable concentrations during a fresh fission product contaminating event. Some of these factors are:

1. type and size of contaminating event,
2. distance from contaminating event and meteorological conditions,
3. feeding patterns (includes many variables),
4. age of animal,
5. whether lactating or not,
6. whether diseased or not, and
7. collection time after event.

All of these variables contribute to the wide range of concentrations found during a given period. Blincoe et al. (*5*) found wide ranges of concentrations for localized herds in Nevada under controlled conditions. Data collected on a nationwide basis would then be expected to show wider variations.

Sensitivity and reporting levels

Measurement of very low concentrations of iodine-131 in bovine thyroids is difficult due to the interference of other radioactive nuclides in the thyroid. Van Middlesworth (*6*) has reported the presence of radium-226 and another unidentified long-lived radionuclide in the thyroid, both of which can be mistakenly identified as iodine-131. The Bovine Thyroid Network routinely reported levels of 1 pCi/g or less as ND (nondetectable) or 0 to allow for possible interference.

[1] Mr. Russell and Mr. Pliner are nuclear engineers in the Nuclear Facilities Branch, Division of Environmental Radiation, Bureau of Radiological Health, 1901 Chapman Avenue, Rockville, Md. 20852.

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It must be emphasized here that the 1 pCi/g sensitivity limit applies only to the routine measurement of bovine thyroids on a large scale where 10 percent of the results (*4*) were verified with a second count. Various investigators (*5,7*) have approached a 0.1 pCi/g sensitivity limit by employing sophisticated counting techniques.

The physiological accumulation of iodine-131 in the thyroid made the Bovine Thyroid Network a sensitive indicator of atmospheric intrusions of fresh fission products. Based on a study in which iodine-131 was administered orally to two Holstein cows, Harris (*8*) reported the ratio of iodine-131 in bovine thyroids in pCi/g to the iodine-131 in milk in pCi/liter to be ≥ 10 from the 2d day to the 19th day after administration and to reach a maximum of about 18 for the 5th through the 9th day. Other investigators (*9,10*) have found this ratio to be 12 and 14, respectively. Extensive controlled environmental radioiodine tests (*11*) also support these ratios. The practical reporting level for bovine thyroids is about 1 pCi/g and for milk is about 10 pCi/liter. The bovine thyroid is then about two orders of magnitude more sensitive than milk in reflecting the presence of iodine-131 in the atmosphere. Harris (*8*) reached this same conclusion in his presentation.

In his earlier paper on the Bovine Thyroid Network, Baratta (*4*) reports an overall sensitivity improvement of 30 for bovine thyroids to milk. This conclusion was based on a ratio of 3 for pCi ^{131}I/g thyroid to pCi ^{131}I/liter milk. However, this conclusion is subject to all the uncertainties listed previously, and in one of his examples (South Dakota), the ratio exceeded 10.

Estimation of human thyroid dose from iodine-131 concentrations in bovine thyroids

Because of the relatively high sensitivity, bovine thyroid data can be used to estimate the dose to the human thyroid when concentrations in milk are below 10 pCi ^{131}I/liter, i.e., Range I of FRC Guidance (*12*). This dose estimate could be used for a single contaminating event if the time of contamination is known or for a continuous contaminating situation where iodine-131 is being deposited on the pasture at a constant rate for a period necessary to achieve equilibrium. The dose estimate is made by using the bovine thyroid to milk ratio discussed here, assuming all human intake is from milk, and using FRC guidance (*12*) for average daily intake or for a single contaminating event. The assumption that all iodine-131 intake is from milk is valid according to Soldat (*13*), especially for children where fresh vegetable intake is small.

For the continuous situation, if the constant level of iodine-131 in bovine thyroids is 12 pCi/g, the milk concentration would be 1 pCi/liter and the dose would be 5 mrem/a to the child's thyroid. In the case of a single contaminating event and a maximum value of 120 pCi/g bovine thyroid, the maximum concentration in milk would be 10 pCi/liter and the dose commitment to the child's 2-gram thyroid would be 1.2 mrad (*14*).

Applying the constant level dose estimation method to the bovine thyroid data reported here is not valid as is evident from figure 1 where concentrations vary by 3 orders of magnitude. The dose probably could be estimated for a single milkshed using the single event method if sufficient data were available for that particular area. However, the results would be subject again to all the uncertainties previously listed.

Analysis

The bovine thyroid data collected by the Bovine Thyroid Network were analyzed for the period October 1964 through February 1969. Table 1 summarizes the results. Positive samples are those for which concentrations were reported. Negative data are reported as "ND" or "0" and indicate that the 2-sigma counting error was greater than the concentration measured. Samples measuring 1 pCi/g or more were used in calculating the percent of positive samples. Also included in this table are nuclear test shots reported in *RHD&R* and nuclear rocket tests which were conducted at the Nevada Test Site (NTS) during May, June, and July 1962.[2] The data presented in *RHD&R* are grouped into 3- and 6-month reporting periods. Interpretation in this format was not possible because iodine-131 has a residence time in the environment of only 2 to 3 months. Thus, the original data were analyzed for monthly periods and the average and maximum values were plotted (figure 1). The percent of positive

[2] Verbal communication from Mr. Frank Grossman, Southwestern Radiological Health Laboratory (SWRHL), Public Health Service, Las Vegas, Nev., October 21, 1969.

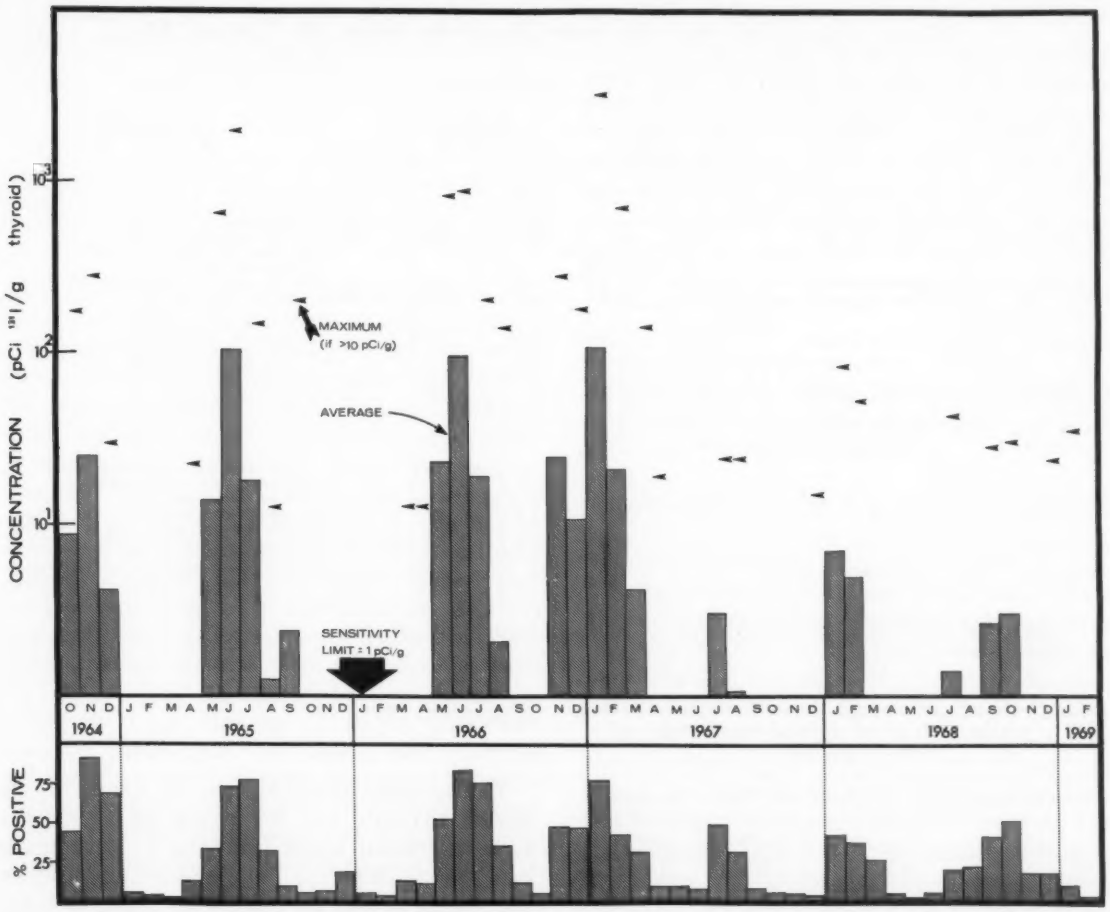
CONCENTRATION (pCi ^{131}I/g thyroid)
MAXIMUM
(if >10 pCi/g)
AVERAGE
SENSITIVITY
LIMIT = 1 pCi/g
O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F
1964
1965
1966
1967
1968
1969
% POSITIVE
75
50
25

Figure 1. Summary of Bovine Thyroid Network, October 1964–February 1969 Monthly averages, maximums, and percent of positive samples

samples for each month is also shown on figure 1. The sudden and large increases in iodine-131 concentrations in bovine thyroids following atmospheric nuclear tests are readily discernible in the plot. To show the close relationship of positive bovine thyroid samples and major atmospheric intrusions of fresh fission products, a chronological list is helpful (table 2).

The transport time for fresh fission product debris from the Chinese mainland to the conterminous United States has been reported to be 3–5 days (*15,16*). The buildup time in the thyroid, after deposition on pasture, varies considerably (*11*) but can be as short as 1 to 2 days. Positive bovine thyroid samples could then be expected in 4 or 5 days after a test on the Chinese mainland. The shortest observed time difference here is 9 days for three different tests and the longest time lag is 18 days for one test. The predominant cause of this variability was the lack of a routine sampling schedule. Most samples were obtained from positive reactors to brucellosis and tuberculosis tests which frequently resulted in sporadic slaughter dates. The geographical coverage also influenced the time factor since many areas of the country did not participate in the program or participated minimally. Other factors which influenced this time lag were discussed in a prior section. Consequently, the Bovine Thyroid Network did not provide an effective alert mechanism for the intrusion of fresh fission products into the atmosphere.

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Table 1. Summary of iodine-131 in bovine thyroids for October 1964–February 1969

Period	*RHD&R* issue	Number of samples	Summary of data				Reported tests (from *RHD&R*)
			Percent positive	Concentration (pCi/g)			
				Average	Minimum	Maximum	
Oct–Dec 64	Oct. 65 (p. 569)	294	60	13	ND	280	Foreign test, Oct. 16, 1964
Jan–June 65	Jan. 66 (p. 49)	1,250	24	19	ND	1,970	Foreign vent, Jan. 15, 1965 NTS excavation, Apr. 14, 1965 Foreign test, May 14, 1965
July–Dec 65	Oct. 66 (p. 601)	1,614	22.6	3.5	ND	206	No atmospheric intrusion tests reported
Jan–June 66	Jan. 67 (p. 51)	1,747	33.3	19	ND	883	NTS vent, Mar. 5, 1966 NTS vent, Apr. 25, 1966 Foreign test, May 9, 1966
July–Dec 66	Apr. 67 (p. 227)	2,401	35.2	9.2	ND	279	Foreign test, July 2, 1966 Foreign test, July 19, 1966 Foreign test, Oct. 27, 1966
Jan–Mar 67	Aug. 67 (p. 465)	1,020	50.1	42	ND	3,260	Foreign test, Dec. 28, 1966
Apr–Sept 67	Feb. 68 (p. 120)	1,356	16.3	<1	ND	22	Foreign test, June 17, 1967 NTS vent, June 29, 1967
Oct–Dec 67	May 68 (p. 280)	676	3.6	<1	ND	15	No atmospheric intrusion tests reported
Jan–Mar 68	Aug. 68 (p. 456)	516	33.7	3.7	ND	83	Foreign test, Dec. 24, 1967 NTS vent, Jan. 18, 1968 NTS excavation, Jan. 26, 1968 NTS excavation, Mar. 12, 1968
Apr–June 68	Nov. 68 (p. 695)	518	3.3	<1	ND	7	[a] Nuclear rocket tests-NTS
July–Sept 68	Feb. 69 (p. 77)	862	26.1	1.3	[b] 0	44	[a] Nuclear rocket tests-NTS NTS excavation experiments
Oct–Dec 68	Apr. 69 (p. 178)	796	28.3	1.3	0	31	NTS excavation, Dec. 8, 1968 Foreign test, Dec. 27, 1968
Jan–Feb 69	Nov. 69 (p. 523)	445	5.1	<1	0	36	No atmospheric intrusion tests reported.

[a] Not reported in *RHD&R*, see text.
[b] Beginning July 1968, concentrations of 1 pCi/g or less (previously reported as ND) are reported as 0.
ND, nondetectable.

Table 2. First positive bovine thyroid samples following major atmospheric intrusions of fresh fission products

Atmospheric nuclear test		First positive bovine thyroid sample		
Date	Location	Date	Concentration (pCi/g)	Location (County, State)
10/16/64	Chinese mainland	10/29/64	174	Erie, N.Y.
5/14/65	Chinese mainland	5/25/65	29	San Luis Obispo, Calif.
5/9/66	Chinese mainland	5/18/66	17	Los Angeles, Calif.
10/27/66	Chinese mainland	11/8/66	109	Knox, Tenn.
12/28/66	Chinese mainland	1/6/67	271	Anderson, Kans.
6/17/67	Chinese mainland	7/5/67	9	Loudon, Tenn.
12/24/67	Chinese mainland	1/2/68	8	Lumpkin, Ga.

Figure 1 also illustrates the 2- to 3-month residence time of iodine-131 in the environment following a major intrusion of fresh fission products. This residence time agrees with 10 physical half-lives or 10 pasture half-times (*17*). In addition to the increases caused by atmospheric testing of nuclear devices, there were 4 months in the absence of testing when the network average was above 1 pCi/g. These periods were September 1965, July 1968, and September–October 1968. Each of these periods is considered separately.

September 1965

The average concentration of iodine-131 in bovine thyroids was 2.4 pCi/g for September 1965. Increased levels from the Chinese mainland test of May 14, 1965, had disappeared by the middle of August 1965. This higher average resulted from four samples collected in the central valley of California on September 13 and 14, 1965 (table 3). Of the total of 72 samples collected in California from September 7 through September 21, 1965, the results of 66 samples were nondetectable; one measured 3 pCi/g; another, 5 pCi/g; and the remaining four are listed in table 3. Of the 13 samples collected from Merced County during this period, 11 were nondetectable. One of six was positive for Fresno County, one of eight was positive for San Joaquin County, and both samples from Santa Clara County were positive.

During a major intrusion of fresh fission products, bovine thyroid samples from a given area are generally all positive, though concentrations can vary considerably. The data from California for September 1965 did not follow this pattern since less than 10 percent (i.e., 6 from a total of 72) were positive and concentrations of only four positive samples were relatively large. Feeding

Table 3. Iodine-131 concentrations in bovine thyroids September 1965

Date (1965)	County	Iodine-131 concentration (pCi/g)
9/13	Fresno	179
9/13	Merced	206
9/13	San Joaquin	55
9/14	Santa Clara	186

patterns could account for this unusual situation, especially in the early fall. The positive concentrations are quite likely valid since iodine-131 was found in milk over a wide area at this time. Iodine-131 was reported (*18*) in milk samples from Denver, Colo., St. Louis, Mo., Albuquerque, N. Mex., Portland, Oreg., and Seattle, Wash., during September 1965. Baratta (*4*) observed a coincident sudden increase of iodine-131 from one of the western United States nuclear installations during this same period. The radiological status report on the Hanford environs for September 1965 (*19*) states, "The concentrations of iodine-131 measured in beef thyroids were generally less than 10 pCi/g. The slightly higher concentrations noted for Pasco samples (25 pCi/g maximum) may be attributable to a slightly above normal release of iodine-131 in early September from the laboratory facilities." It appears that the iodine-131 found in bovine thyroids and milk during this period came from the Hanford facilities.

July 1968

The average concentration of iodine-131 in 287 bovine thyroid samples for July 1968 was 1.34 pCi/g. There were no major tests reported during this period; however, there were a number of nuclear rocket engine tests conducted at the Nevada Test Site (NTS) during this period. The largest reactor engine tested was the Phoebus-2A which was run at various power levels on May 29, June 8 and 26, and July 18, 1968.[2] Since this reactor engine was run under different conditions than the Phoebus-1B runs (*20*), it was estimated that the release of iodine-131 during the Phoebus-2A runs amounted to some hundreds of curies.[3] These runs were performed with the exhaust upward, and the effective plume height would be on the order of 1,000 to 10,000 feet resulting in dispersion by prevailing winds. Most of the positive samples for July 1968 were collected in Colorado, South Dakota, and Wyoming. Other positive samples were near the sensitivity limit (see discussion on sensitivity and reporting levels) and widely scattered. These positive results from Colorado and South Dakota cannot be attributed to nuclear power reactors since there are none in this area. The Elk River plant in central Minnesota, and Pathfinder located in South Dakota, were shutdown during this period (*21*). There were no nuclear power plants operating in Colorado or any State adjacent to Colorado. Therefore, the nuclear rocket tests at NTS were probably the source of iodine-131 during this period.

September–October 1968

During September 1968, there appeared to be a major intrusion of iodine-131 into the atmosphere. The average concentration for September was 2.6 pCi/g and nearly 40 percent of all samples were positive, indicating widespread contamination. The average concentration was 2.9 pCi/g in October 1968 and the number of positive samples increased to 50 percent of all samples collected. In contrast, the number of positive samples for July 1968 was 19 percent of the total. The maximum concentration in July 1968 was 44 pCi/g; however, the maximum concentrations reached only 29 pCi/g in September 1968 and 31 pCi/g in October 1968. The source of iodine-131 causing these widespread positive concentrations could not be found in the available literature; however, a series of nuclear tests were conducted in the South Pacific during this period.

Discussion

While the Bovine Thyroid Network proved to be a sensitive indicator of iodine-131 in the atmosphere, it did not serve adequately as an alert mechanism. Several of the many variables affecting the concentration of iodine-131 in bovine thyroids contributed to this failure. The most important factor contributing to this inadequacy is that iodine apparently does not build up in the thyroid as quickly as in milk (*8,11*).

The network gave additional documentation of fallout levels as determined by other surveillance programs, especially the Pasteurized Milk

[3] Personal communication from Mr. John J. Lane, Space Nuclear Propulsion Office, Atomic Energy Commission.

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Network. It appeared to reflect the selective release of iodine-131 during September 1965 when air filter sampling failed to show an increase in environmental levels. Bovine thyroid sampling also proved useful in documenting situations where iodine-131 levels were low and below the detection limit in milk as during the summer and fall of 1968.

The use of bovine thyroids for routine surveillance of nuclear facilities does not appear to be feasible in spite of their high sensitivity ($\sim$1.0 pCi/g). Federal regulations restrict the discharge of iodine-131 from nuclear power installations because of its rapid assimilation into the food chain. If the small quantities of iodine-131 routinely discharged from nuclear power plants were sufficient to produce measurable concentrations in bovine thyroids, a relatively constant level of iodine-131 in bovine thyroids would be expected. This effect has not been observed. Bovine thyroid concentrations were below minimum detectable limits for all periods in which there were no atmospheric intrusions with the exception of the fall of 1968. Kahn (7) reported low concentrations ($\leq$0.5 pCi/g) of iodine-131 in bovine thyroids in his study of Dresden. However, he was unable to definitely establish the source of this iodine. If Dresden Nuclear Power Station is assumed to be the source of the iodine-131, the Bovine Thyroid Network, as previously operated, would not be sufficiently sensitive to measure levels caused by the nuclear installation.

Estimation of dose of the human thyroid using bovine thyroid data from a national network is of questionable validity. Under controlled conditions human thyroid doses could quite probably be estimated with accuracy, although analysis of the milk would be preferred since milk is the major intake contributor.

Summary

A detailed analysis of the bovine thyroid data from October 1964 through February 1969, as reported in *RHD&R*, shows that most positive results can be related to various nuclear tests with known atmospheric intrusions. The widespread nature of various samples having positive concentrations of short-lived fission products and the rapid increase of levels in these samples indicate the source to be a major atmospheric intrusion. Routine, low-level discharges from nuclear power plants would not, in our opinion, give rise to sudden, nationwide increases in radionuclide concentrations.

Estimates determining thyroid dose in man from iodine-131 concentrations in bovine thyroids appear to be feasible under selected conditions but are of little use in evaluating nationwide network data. The lower limit of detectability is 1 pCi ^{131}I/g bovine thyroid and most samples at this level have a 2-standard deviation error greater than the measured quantity.

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Results of 33,911 X-ray Protection Surveys of Facilities with Medical or Dental Diagnostic X-ray Equipment, Fiscal Years 1961-1968

Lawrence R. Fess, Richard B. McDowell, Wayne R. Jameson and *Ray W. Alcox*[1]

The results of radiation surveys of 33,911 medical and dental x-ray facilities are presented and analyzed. It was found that a high percentage of x-ray machines in medical facilities have improper collimation and inadequate filtration. In addition, a large proportion of the facilities do not possess adequate accessory patient or operator shielding. The use of an open-end aiming device, high-speed film, and the need to improve darkroom procedures were the primary recommendations made for dental facilities.

Data from x-ray protection surveys of 12,847 medical and 21,064 dental x-ray facilities, conducted by State radiological health personnel in 25 States and two territories, were available (as of June 30, 1968) for analysis by the Bureau of Radiological Health (BRH). These States and territories had programs in various stages of development with respect to regulations and recommendations for x-ray protection and their interpretation. The dental surveys were conducted from fiscal year (FY) 1961-FY 1968; the medical surveys, from FY 1963-FY 1968. The data, collected on standardized forms supplied by the Public Health Service (PHS), (appendix 1, figures 11–18) were analyzed for information from which frequency distributions on selected items of interest were generated. For the medical x-ray protection surveys, the standardized forms used were: Facility Form (PHS 4495-1), Fluoroscopic Form (PHS 4495-2), and Radiographic Form (PHS 4495-3); for dental surveys, form PHS 3657 was used. The medical x-ray forms were revised in July 1965. Those forms printed prior to that date are designated "old forms," and those forms printed after July 1965 are called "new forms." The revision resulted in the deletion, change, or addition of some items to the new form. Where these items occur in the tables, a footnote indicates whether they came from the "old" or "new" forms.

The frequency distribution tables provide a summation of data from the medical and dental x-ray protection survey report forms. Information is presented by facility category, equipment type and usage, and equipment status as related to the recommendations of the National Committee on Radiation Protection as published in the National Bureau of Standards (NBS) Handbook 76 and workload as related to the type of machine and category of user. For purposes of definition, a facility is an address having one or more x-ray machines, and an x-ray machine consists of an x-ray tube with the necessary appurtenances to permit its use for radiographic and/or fluoroscopic procedures.

The medical radiographic and fluoroscopic examination data are related to the two most usual procedures reported to have been performed on an "average" or "standard" man with the x-ray equipment located in the 12,847 medical facilities. The examination data are presented according to the most frequently reported radiographed and fluoroscoped body areas: chest, abdomen, extremities, and spine for radiography; chest and gastrointestinal tract for fluoroscopy. All remaining types of radiographic examinations are included in the "all other" category. Because of the provision on the radiographic and fluoroscopic survey forms for reporting the two most usual procedures performed on each machine, the number of procedure reports could theoretically be double the number of machines. As expected, however, information about a second procedure on a machine was often lacking. This

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occurred more frequently in the case of fluoroscopic machines. Although many of these machines were physically surveyed, no procedure information was obtained because the fluoroscopic capability was not used. Hence, although 4,849 machines with fluoroscopic capability were physically surveyed, there were only 5,388 reports of procedures rather than the 9,698 that were theoretically possible.

Selected highlights

Medical X-ray Protection Surveys

Personnel data by type of facility

The 12,847 medical x-ray facilities are listed by the major types of facility (or practice) in descending order of magnitude of their radiographic workload. The highest workloads are reported for radiologists, hospitals, and multiple specialty clinics. The "all others" category contains specialty groups that were too small in number to permit comparison with the larger practitioner categories in this sample.

As expected, those categories with high workloads ranked high in both average number of personnel occupationally exposed and in average number of x-ray machine operators per facility (table 1). At the same time, it is within these high workload categories that the highest percentage of occupationally exposed persons and machine operators, who are being monitored for their radiation exposure, are found. However, the data from the facilities with lower workloads suggests the need for closer observation of the operator levels of exposure and possible recommendations of additional personnel monitoring.

Equipment and darkroom data by type of facility

Figures presented in the first section of table 2 indicate that the larger machine-per-facility ratios are found in facilities with greater workloads or where one would expect multiple procedures to be performed. This is also evident, when examining the ratio of x-ray tubes to machines, since the same facilities tend to have multitube machines.

Certain facilities in the second section of table 2 are reported to have no darkrooms. This may be explained, in part, by the use of vertical fluoroscopes, some of which require no darkroom facilities, and partially by the increase in the use of automatic processors which the surveyor may not have considered to be in a "darkroom" in the technical sense of the word.

Workload by type of facility

Table 3 presents the workload data that provided the basis for ranking the specialties in the tables appearing in this report.

Table 1. Personnel data by type of facility (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Personnel characteristics	Type of facility or type of practice										
	Radiologists	Hospitals	Multiple specialty clinics	Internists	General practitioners in clinics	General practitioners in private practice	Osteopaths	Chiropractors	Podiatrists	All others	All facilities
Average number of persons occupationally exposed per facility surveyed	4.4	6.5	4.3	2.4	3.2	2.1	1.6	1.2	1.3	2.6	2.8
Average number of x-ray machine operators per facility surveyed	3.8	5.6	3.1	1.7	2.6	1.8	1.5	1.1	1.2	1.9	2.3
Average number of persons monitored per facility surveyed	3.2	5.3	2.2	.3	.8	.3	.1	.1	.1	.6	1.2
Ratio of x-ray machine operators to total persons occupationally exposed	.87	.85	.75	.71	.81	.85	.90	.94	.89	.73	.82
Percent of persons occupationally exposed who are monitored	71.7	80.8	49.6	14.3	23.3	12.3	7.1	9.8	7.8	23.3	41.0
Percent of x-ray machine operators who are monitored	82.4	95.0	66.0	20.2	28.7	14.4	7.9	10.4	8.8	31.8	50.0
Number of facilities	435	1,727	297	749	413	3,119	287	1,718	806	3,296	12,847

Table 2. Equipment and darkroom data by type of facility (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Equipment and darkroom characteristics	Type of facility or type of practice										
	Radiologists	Hospitals	Multiple specialty clinics	Internists	General practitioners in clinics	General practitioners in private practice	Osteopaths	Chiropractors	Podiatrists	All others	All facilities
Equipment:											
Average number of x-ray machines per facility surveyed	2.2	3.8	1.5	1.1	1.2	1.0	1.0	1.0	1.0	1.2	1.5
Average number of x-ray tubes per facility surveyed	3.5	5.1	2.0	1.2	1.5	1.1	1.1	1.0	1.0	1.3	1.8
Ratio of x-ray tubes to machines	1.6	1.3	1.3	1.1	1.3	1.1	1.1	1.0	1.0	1.1	1.2
Darkroom:											
Percent of facilities surveyed with no darkroom	3.2	6.4	10.4	24.4	5.8	12.0	5.2	9.5	8.4	14.1	11.0
Percent of darkrooms surveyed that were lighttight	83.8	77.7	80.5	67.5	74.8	72.1	87.1	74.3	86.0	78.9	76.4
Percent of facilities surveyed with automatic film processing capability	30.6	22.7	8.4	1.6	2.4	2.1	1.0	1.1	3.7	2.0	6.3
Number of facilities	435	1,727	297	749	413	3,119	287	1,718	806	3,296	12,847

Table 3. Workload data by type of facility (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Workload characteristics	Type of facility or type of practice										
	Radiologists	Hospitals	Multiple specialty clinics	Internists	General practitioners in clinics	General practitioners in private practice	Osteopaths	Chiropractors	Podiatrists	All others	All facilities
Radiographic exposures[a]											
Number of facilities reporting	192	840	172	256	258	1,606	133	898	299	1,198	5,852
Average per facility per week	485	421	129	28	63	17	11	8	6	83	108
Patients radiographed[b]											
Number of facilities reporting	228	843	118	229	144	1,195	136	791	483	937	5,104
Average per facility per week	104	189	114	20	45	14	8	5	4	63	57
Fluoroscopic examinations[a]											
Number of facilities reporting	187	729	85	289	107	468	35	19	2	398	2,319
Average per facility per week	25	28	12	10	8	5	[c]	[c]	[c]	14	16
Patients fluoroscoped[b]											
Number of facilities reporting	222	742	41	195	53	345	13	9	2	212	1,834
Average per facility per week	20	33	29	10	5	9	[c]	[c]	[c]	13	21

[a] Data available from "old" facility form PHS-4495-1 only.
[b] Data available from "new" facility form PHS-4495-1 only.
[c] Frequency too small to permit valid calculation.

Table 4. Distribution of diagnostic x-ray equipment by type of machine (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

X-ray equipment					
Radiographic			Fluoroscopic		
Type	Number	Percent	Type	Number	Percent
Fixed	11,329	77.0	Tilting[a]	3,830	79.0
Mobile	2,806	19.1	Vertical	905	18.7
Photofluorographic	208	1.4	Other[b]	114	2.3
Other[b]	374	2.5	Total	4,849	100.1
Total	14,717	100.0			
Of the total number of radiographic machines, 40.9 percent have fluoroscopic capability			Of the total number of fluoroscopic units, 80.9 percent have radiographic capability		

[a] Includes horizontal table-type fluoroscopes.
[b] Includes coding error, not reported, and undetermined.

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Distribution of diagnostic x-ray equipment by type of machine

The distribution of medical radiographic and fluoroscopic equipment by machine type is presented in table 4. The greatest percentage of radiographic machines are classified as fixed, with approximately one-half of the fixed machines (5,586) having fluoroscopic capability.

Radiographic workload per machine by type of facility

Table 5 reflects the workload in terms of radiographic exposures per week, per machine, and patients radiographed per week, per machine. The distributions are similar to those presented in table 3.

Table 5. Radiographic workload per machine by type of facility (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Radiographic workload per machine	Type of facility or type of practice										
	Radiologists	Hospitals	Multiple specialty clinics	Internists	General practitioners in clinics	General practitioners in private practice	Osteopaths	Chiropractors	Podiatrists	All others	All facilities
Radiographic exposures:[a]											
Number of machines for which radiographic exposures were reported	353	2,310	215	288	267	1,551	129	884	291	817	7,105
Average per machine per week	193	115	95	26	60	17	11	9	7	63	66
Patients radiographed:[b]											
Number of machines for which patients radiographed were reported	346	2,674	171	300	148	1,169	136	766	468	654	6,832
Average per machine per week	56	50	79	46	34	14	8	5	5	45	35

[a] Data available from "old" radiographic form PHS-4495-3 only.
[b] Data available from "new" radiographic form PHS-4495-3 only.

Table 6. Distribution of radiographic machines by recommendations as specified in NBS Handbook 76 (*1*) and by type of facility (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Recommendations	Type of facility or type of practice										
	Radiologists	Hospitals	Multiple specialty clinics	Internists	General practitioners in clinics	General practitioners in private practice	Osteopaths	Chiropractors	Podiatrists	All others	All facilities
Gonadal shields for patients:											
Number of reports	697	4,571	360	555	395	2,586	247	1,553	699	1,376	13,039
Percent in compliance	(75.6)	(63.9)	(68.0)	(38.7)	(47.8)	(45.6)	(31.6)	(33.4)	(13.4)	(47.6)	(50.8)
Filtration not less than 2.5 mm. of aluminum equivalent:											
Number of reports	706	4,884	379	560	407	2,712	267	1,641	736	1,458	13,750
Percent in compliance	(85.8)	(71.2)	(59.9)	(57.0)	(52.3)	(41.5)	(35.2)	(60.1)	(27.8)	(57.8)	(58.9)
Adequate exposure switch location:											
Number of reports	727	5,137	387	593	422	2,744	264	1,627	768	1,526	14,195
Percent in compliance	(73.0)	(82.5)	(88.1)	(70.0)	(92.4)	(86.4)	(89.4)	(91.3)	(68.5)	(84.6)	(83.3)
Adequate operator protection:											
Number of reports	719	5,005	387	590	417	2,712	253	1,622	769	1,493	13,967
Percent in compliance	(98.9)	(97.5)	(96.6)	(90.0)	(93.8)	(88.8)	(90.5)	(93.9)	(79.1)	(93.8)	(93.5)
Adequate primary and secondary barrier:											
Number of reports	703	4,300	381	578	412	2,686	256	1,617	767	1,444	13,144
Percent in compliance	(98.6)	(96.0)	(94.2)	(90.5)	(92.7)	(92.0)	(94.9)	(96.8)	(95.2)	(94.2)	(94.6)
Deadman type switch[a]:											
Number of reports	364	2,317	219	290	273	1,578	133	892	297	851	7,214
Percent in compliance	(97.8)	(99.0)	(98.6)	(100.0)	(99.6)	(99.6)	(100.0)	(91.7)	(99.3)	(97.1)	(98.0)
Diagnostic type tube housing:											
Number of reports	650	4,270	296	515	336	2,430	183	1,510	749	1,374	12,313
Percent in compliance	(99.2)	(98.8)	(100.0)	(96.5)	(99.1)	(98.3)	(97.8)	(97.5)	(98.9)	(98.4)	(98.5)
Timer terminates exposure:[a]											
Number of reports	366	2,317	220	289	273	1,573	131	895	297	851	7,212
Percent in compliance	(99.2)	(99.8)	(100.0)	(99.6)	(99.3)	(99.2)	(99.2)	(98.4)	(99.0)	(99.3)	(99.3)

[a] Data available from "old" radiographic form PHS-4495-3 only.

Table 7. Fluoroscopic workload by type of facility (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Type of facility	Fluoroscopic workload (Averages are per machine per week)									
	Examination type						Spot films		Total number of milliampere-minutes[b]	
	Chest[a]		Gastrointestinal		Other					
	Number of reports	Average	Number of reports	Average	Number of reports	Average	Number of reports	Average	Number of reports	Average
Radiologists	142	11.3	638	10.6	91	7.1	353	72.1	219	145
Hospitals	433	10.6	2,215	13.3	345	14.7	1,234	84.8	889	159
Multiple specialty clinics	65	8.3	131	15.0	18	14.4	95	58.5	50	247
Internists	304	6.5	225	6.9	117	7.1	77	24.8	194	46
General practitioners	316	5.1	509	4.9	239	4.3	225	18.1	330	30
All other facilities	144	6.2	266	8.4	79	3.5	123	64.9	124	83
All facilities	1,404	8.0	3,984	11.2	889	7.1	2,107	71.1	1,806	119

[a] Data available from "old" fluoroscopic form, PHS-4495-2 only.
[b] Data available from "new" fluoroscopic form, PHS-4495-2 only.

Table 8. Distribution of fluoroscopic machines by recommendations as specified in NBS Handbook 76 (*1*) and by type of facility (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Recommendations	Type of facility						
	Radiologists	Hospitals	Multiple specialty clinics	Internists	General practitioners	All others	All facilities
Leaded drapes around screen:							
Number of reports	507	1,950	163	507	954	396	4,477
Percent in compliance	(45.2)	(40.9)	(21.5)	(11.2)	(12.9)	(19.9)	(29.5)
Bucky slot covers:							
Number of reports	514	1,938	155	396	859	368	4,230
Percent in compliance	(55.4)	(65.1)	(31.6)	(16.7)	(20.0)	(29.1)	(45.9)
Manually reset cumulative timer:							
Number of reports	516	2,000	164	631	1,030	447	4,788
Percent in compliance	(61.0)	(62.8)	(39.6)	(28.5)	(24.4)	(31.3)	(46.1)
Useful beam limited to screen:							
Number of reports	504	1,942	160	612	982	430	4,630
Percent in compliance	(79.4)	(75.4)	(59.4)	(48.4)	(47.8)	(57.4)	(64.2)
Filtration not less than 2.5 mm. of aluminum equivalent:							
Number of reports	355	1,292	124	449	829	355	3,404
Percent in compliance	(94.6)	(90.9)	(83.1)	(66.6)	(54.2)	(60.6)	(75.7)
Roentgen output is 10 R/min or less:							
Number of reports	503	1,903	160	596	943	393	4,518
Percent in compliance	(94.2)	(94.8)	(88.1)	(74.7)	(79.2)	(82.4)	(87.1)
Leaded apron:							
Number of reports	521	2,024	169	636	1,076	461	4,887
Percent in compliance	(99.2)	(98.7)	(97.0)	(95.6)	(86.3)	(90.0)	(95.2)
Leaded gloves:							
Number of reports	521	2,026	168	635	1,064	461	4,875
Percent in compliance	(98.6)	(98.4)	(98.2)	(93.8)	(90.2)	(93.0)	(96.5)
Leaded screen is satisfactory:[a]							
Number of reports	232	891	58	245	414	141	1,981
Percent in compliance	(97.8)	(98.0)	(96.6)	(93.9)	(85.9)	(96.4)	(96.5)
Within target-to-panel distance limits:							
Number of reports	484	1,859	148	606	972	421	4,490
Percent in compliance	(100.0)	(99.5)	(98.6)	(94.1)	(91.6)	(95.5)	(96.9)
Screen is ganged to x-ray tube:							
Number of reports	514	1,993	166	625	1,022	444	4,764
Percent in compliance	(99.8)	(99.6)	(95.8)	(97.4)	(96.0)	(94.4)	(97.9)
Deadman exposure switch:							
Number of reports	515	1,989	162	625	1,018	441	4,750
Percent in compliance	(99.6)	(99.0)	(99.4)	(98.6)	(98.9)	(98.2)	(98.9)

[a] Data available from "new" fluoroscopic form, PHS-4495-2 only.

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Distribution of radiographic machines by recommendations as specified in NBS Handbook 76 and by type of facility

Table 6 reflects the extent to which the surveyed x-ray equipment complied with those recommendations of the NBS Handbook 76 (*1*) considered to be most important from the standpoint of radiation safety. The data indicate that the use of gonadal shields as a means of reducing genetic dose has not obtained widespread usage, that insufficient filtration is frequently encountered in many machines and that some operators may be unnecessarily exposed because of location of the exposure switch.

Fluoroscopic workload by type of facility

Table 7 shows the workload per machine, per week, by type of facility. As in other related tables, the greatest workloads are found in hospitals, radiologists' offices, and multiple specialty clinics.

Distribution of fluoroscopic machines by recommendations as specified in NBS Handbook 76 and and by type of facility

Table 8 indicates several fluoroscopic problem areas: inadequate filtration, lack of manually reset cumulative timers, useful beam not limited to screen, no Bucky slot covers or leaded drapes around screen, and in some facilities excessive roentgen output at the panel or table top. It is interesting to note that general practitioners and internists tend to have equipment that is deficient in these items more frequently than other types of facilities. It is felt that this may be due partly to the use of older fluoroscopic machines.

Distribution of fluoroscopic machines by items of special interest and by type of facility

In table 9, two items of special interest are: the distribution of image intensifying devices, and the amount of time used for dark adaptation by the different types of facilities. There appears to be some correlation between image intensifying devices and dark adaptation in those facilities where the majority of these devices are located, except for the general practitioner category for which 17.6 percent reported no dark adaptation. The majority of the image intensifying devices whose use results in lower patient exposure are found in high workload facilities.

Distribution of radiographic procedure reports by body area of examination and by type of facility

Table 10 shows the distribution of the four major body areas of examination by type of facility. Radiographic procedures were performed most frequently on the chest except in those facilities where one would not expect the chest examination to be one of the two most usual radiographic procedures (e.g., podiatrist).

Distribution of radiographic procedure reports by body area of examination and by type of machine

Table 11 shows the distribution of the body areas of examination by type of machine used. For the fixed radiographic and photofluorographic machines, the largest percentage of reports are of chest examination procedures, but for mobile radiographic machines, the largest percentage of reports are of the "all other" category of examination procedures. The larger "all other" examination percentage for this mobile machine category may be explained by the fact that the majority of these machines were located in hospitals where their use is varied.

Percent distribution of radiographic procedure reports by kilovolt peak, milliampere-second, film size, source to film distance, beam shape, and by body area of examination

Tables 12 to 16 show the wide variation in technique parameters that were reported used for the four major body areas of examinations.

Percent distribution of radiographic procedure reports by collimation as reported by surveyor and by body area of examination

Table 17 presents a summary of the collimation status of radiographic procedures relatable to the size of the film receptor as subjected to interpretation by the surveyor of his respective State program regulations and/or recommendations at the time of survey. From this table, it is evident that improper collimation of the useful beam is a problem of considerable magnitude for all body areas of examination.

Table 9. Distribution of fluoroscopic machines by items of special interest and by type of facility (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Items of special interest	Type of facility						
	Radiologists	Hospitals	Multiple specialty clinics	Internists	General practitioners	All others	All facilities
Image intensifying device:							
Number of reports	512	2,003	158	636	1,071	470	4,850
Percent having device	(20.1)	(25.6)	(10.8)	(1.7)	(2.0)	(7.9)	(14.5)
Dark adaptation (minutes):[a]							
Number of reports	876	140	451	475	1,795	275	4,012
Percent reporting none	(11.4)	(10.0)	(4.2)	(7.7)	(17.6)	(13.1)	(13.0)
10 or less	(40.8)	(20.0)	(47.7)	(19.4)	(14.3)	(50.9)	(27.1)
11–15	(21.3)	(26.4)	(31.5)	(27.4)	(25.6)	(23.3)	(25.4)
Greater than 15	(26.5)	(43.6)	(16.6)	(45.5)	(42.5)	(12.7)	(34.5)
Lighttight room:							
Number of reports	469	1,726	135	582	909	343	4,214
Percent in compliance	(90.0)	(83.9)	(81.5)	(83.3)	(78.3)	(59.6)	(82.4)

[a] No set time is required for dark adaptation as this varies with the equipment used and the ability and age of user. However, at least 10 minutes is recommended when no image intensification is used.

Table 10. Distribution of radiographic procedure reports by body area of examination and by type of facility (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Type of facility	Body area of examination													
	Chest		Abdomen		Extremity		Spine		All others		Unknown[a]		All body areas	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Radiologists	571	38.6	347	23.4	135	9.1	94	6.4	230	15.5	103	7.0	1,480	100.0
Hospitals	3,289	31.2	1,667	15.8	1,027	9.7	410	3.9	2,363	22.4	1,790	17.0	10,546	100.0
Multiple specialty clinics	303	38.3	97	12.2	102	12.9	54	6.8	132	16.7	104	13.1	792	100.0
Internists	579	48.2	83	6.9	102	8.5	32	2.7	173	14.4	231	19.3	1,200	100.0
General practitioners:														
Clinics	388	45.4	110	12.9	196	23.0	20	2.3	101	11.8	39	4.6	854	100.0
Private practice	2,328	41.4	557	9.9	1,170	20.8	168	3.0	792	14.1	605	10.8	5,620	100.0
Osteopaths	179	32.5	38	6.9	132	24.0	47	8.6	100	18.2	54	9.8	550	100.0
Podiatrists	4	.2	5	.3	719	45.4	120	7.6	275	17.4	461	29.1	1,584	100.0
Chiropractors	106	3.1	29	.9	69	2.1	1,787	53.1	782	23.2	593	17.6	3,366	100.0
All others	731	23.5	251	8.0	466	15.0	275	8.8	912	29.3	479	15.4	3,114	100.0
Total number of reports	8,478	29.1	3,184	10.9	4,118	14.2	3,007	10.3	5,860	20.2	4,459	15.3	29,106	100.0

[a] Includes coding error, not performed, not reported, and undetermined.

Table 11. Distribution of radiographic procedure reports by body area of examination and by type of machine (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Type of radiographic machine	Body area of examination													
	Chest		Abdomen		Extremity		Spine		All others		Unknown[a]		All body areas	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Fixed	6,809	30.2	2,900	12.9	3,259	14.5	2,649	11.7	4,001	17.7	2,938	13.0	22,556	100.0
Photofluorographic	207	43.9	27	5.7	25	5.3	15	3.2	102	21.6	96	20.3	472	100.0
Mobile	1,262	23.7	224	4.2	762	14.3	301	5.7	1,475	27.8	1,292	24.3	5,316	100.0
Other and unknown[a]	200	26.2	33	4.3	72	9.5	42	5.5	282	37.0	133	17.5	762	100.0
Total number of reports	8,478	29.1	3,184	10.9	4,118	14.2	3,007	10.3	5,860	20.2	4,459	15.3	29,106	100.0

[a] Unknown includes coding error, not performed, not reported, and undetermined.

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Table 12. Percent distribution of radiographic procedure reports by kilovolt peak and by body area of examination (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Kilovolt peak	Body area of examination (percent)						
	Chest (N=8,478)	Abdomen (N=3,184)	Extremity (N=4,118)	Spine (N=3,007)	All other (N=5,860)	Unknown[a] (N=4,459)	All body areas (N=29,106)
Less than 60	5.8	3.2	49.3	6.8	12.0	3.5	12.7
60–69	29.0	20.6	27.2	25.9	11.8	3.9	20.2
70–79	38.9	40.8	9.5	37.9	16.7	2.9	24.9
80–89	15.2	23.0	3.1	20.5	8.5	2.4	11.6
90–99	3.1	5.6	1.1	3.5	1.7	.4	2.4
100 and over	2.7	6.3	3.5	2.6	34.8	1.3	9.4
Unknown[a]	5.3	.5	6.3	2.8	14.5	85.6	18.8

[a] Includes coding error, not performed, not recorded, and undetermined.

Table 13. Percent distribution of radiographic procedure reports by milliampere-seconds and by body area of examination (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Milliampere-seconds	Body area of examination (percent)						
	Chest (N=8,478)	Abdomen (N=3,184)	Extremity (N=4,118)	Spine (N=3,007)	All other (N=5,860)	Unknown[a] (N=4,459)	All body areas (N=29,106)
Less than 10	24.8	37.1	35.0	9.9	11.3	2.2	19.9
10–19	57.0	1.6	21.8	5.2	5.0	2.3	21.8
20–29	7.8	3.0	9.3	5.3	4.6	1.1	5.5
30–39	1.9	3.6	6.1	4.6	4.6	.9	3.4
40–49	.8	4.0	3.4	4.1	3.4	.8	2.4
50–74	1.2	27.5	13.9	23.8	14.6	1.3	10.9
75–99	.7	11.8	4.4	19.4	6.5	.8	5.5
100 or more[b]	1.0	9.2	3.1	23.3	4.7	4.5	5.8
Phototimer	.7	.2	.1	.8	.4	[c]	.4
Unknown[a]	4.1	2.0	2.9	3.6	44.9	86.1	24.4

[a] Includes coding error, not performed, not recorded, and undetermined.
[b] Data available from "new" radiographic form PHS-4495-3 only.
[c] Less than 0.1 percent.

Table 14. Percent distribution of radiographic procedure reports by film size and by body area of examination (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Film size (inches)	Body area of examination (percent)						
	Chest (N=8,478)	Abdomen (N=3,184)	Extremity (N=4,118)	Spine (N=3,007)	All other (N=5,860)	Unknown[a] (N=4,459)	All body areas (N=29,106)
8 by 10	0.5	1.0	34.8	18.7	9.5	4.5	9.7
10 by 12	1.4	27.4	49.0	18.2	22.5	3.1	17.2
14 by 17	94.0	66.7	12.4	51.0	20.0	5.7	46.6
Other[b]	2.1	2.0	2.5	10.6	3.1	.7	3.0
Unknown[a]	2.0	2.9	1.3	1.5	44.9	86.0	23.5

[a] Includes coding error, not performed, not recorded, and undetermined.
[b] Includes 5- by 7-, 14- by 36-, and 8- by 36-inch films, and photofluorographic films.

Table 15. Percent distribution of radiographic procedure reports by source to film distance and by body area of examination (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Source to film distance (inches)	Body area of examination (percent)						
	Chest (N=8,478)	Abdomen (N=3,184)	Extremity (N=4,118)	Spine (N=3,007)	All other (N=5,860)	Unknown[a] (N=4,459)	All body areas (N=29,106)
Less than 36	2.7	43.5	41.3	27.9	19.7	3.8	18.8
36–39	3.1	7.0	22.4	23.3	10.3	4.5	10.0
40	4.3	26.4	20.1	19.4	13.1	3.5	12.2
41–71	9.2	18.4	13.2	24.6	10.6	1.5	11.4
72 or more	80.0	2.3	2.2	4.0	2.4	1.2	25.0
Unknown[a]	.7	2.4	.8	.8	43.9	85.5	22.6

[a] Includes coding error, not performed, not reported, and undetermined.

Table 16. Percent distribution of radiographic procedure reports by beam shape and by body area of examination (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Beam shape	Body area of examination (percent)						
	Chest (N=8,478)	Abdomen (N=3,184)	Extremity (N=4,118)	Spine (N=3,007)	All other (N=5,860)	Unknown[a] (N=4,459)	All body areas (N=29,106)
Circular	61.5	41.1	71.2	60.7	30.9	10.8	46.6
Square	6.1	30.1	8.8	13.6	8.6	.7	9.6
Rectangular	27.1	15.5	13.8	18.1	10.8	2.5	16.0
Unknown[a]	5.3	13.3	6.2	7.6	49.7	86.0	27.8

[a] Includes coding error, not performed, not recorded, and undetermined.

Table 17. Percent distribution of radiographic procedure reports by collimation as reported by surveyor and by body area of examination (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Collimation	Body area of examination (percent)						
	Chest (N=8,478)	Abdomen (N=3,184)	Extremity (N=4,118)	Spine (N=3,007)	All other (N=5,860)	Unknown[a] (N=4,459)	All body areas (N=29,106)
Proper collimation[b]	57.9	76.5	62.5	69.8	50.7	17.2	54.1
Improper collimation[c]	36.3	20.3	34.6	24.1	32.8	7.8	28.0
Unknown[a]	5.8	3.2	2.9	6.1	16.5	75.0	17.9

[a] Includes coding error, not performed, not recorded, and undetermined.
[b] Includes variable collimator and permanent collimation installed by surveyor.
[c] Includes "proper cone not available."

Percent distribution of radiographic procedure reports by collimation as determined from beam diameter and film size and by fiscal year period

Table 18 presents collimation data comparing the film size to the diameter or diagonal of the useful beam-dimensions which were recorded separately from the surveyor's judgment of collimation as reported in table 17. As seen in table 18 this method of evaluating collimation is more conservative than the surveyor's judgment and even though progress has been made throughout the years there remains room for substantial improvement.

Beam diameter as reported for a 14-by 17-inch film used with circular collimation by type of facility

Table 19 presents collimation data as reported for a 14- by 17-inch film used with circular-shaped beam by type of facility according to recommendations of the National Council on Radiation Protection and Measurements (NCRP) Report No. 33 (*2*). NCRP Report No. 33 states that "the size of the x-ray beam projected by fixed aperture cones and collimators should not exceed the dimensions of the x-ray film by more than 2 inches for a source-film distance of 72 inches or 1 inch for a source-film distance of 36 inches." Hence, the upper limit of the beam diameter of a circular collimator used with a 14- by 17-inch film at 72 inches is 16 inches. When one applies this criterion to the survey data, it becomes evident that collimation of the useful beam according to present day recommendations is totally inadequate.

Beam diameter as reported for a 14- by 17-inch film used with circular collimation by fiscal year periods

Table 20 presents the collimation data contained in table 19 for three fiscal year periods. Essentially no change is noted during this time period.

Distribution of fluoroscopic procedure reports by body area of examination and by type of facility

Table 21 shows that the radiologists and hospitals are performing the majority of the fluoroscopic examinations. When this information is compared with the data contained in tables 6 and 8, it is evident that better protection is being

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Table 18. Percent distribution of radiographic procedure reports by collimation as determined from beam diameter[a] and film size by fiscal year periods (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Collimation as determined from beam diameter[a] and film size	Fiscal year periods							
	1963–1964		1965–1966		1967–1968		All periods	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Appropriate for size of film used[b]	817	40.0	5,502	49.8	4,456	67.9	10,775	54.8
Excessive for size of film used[c]	1,228	60.0	5,536	50.2	2,107	32.1	8,871	45.2
Total number of reports	2,045	100.0	11,038	100.0	6,563	100.0	19,646	100.0

[a] Or diagonal.
[b] Beam diameter or diagonal is less than or equal to 11 inches for 5- by 7-inch film; 15 inches for an 8- by 10-inch film; 18 inches for a 10-by 12-inch film; 24 inches for a 14-by 17-inch film.
[c] Beam diameter or diagonal exceeds limitations in footnote [b].

Table 19. Beam diameter as reported for 14- by 17-inch film used with circular collimation by type of facility (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Type of facility	Beam diameter					
	16 inches or less (*2*)		Greater than 16 inches		Total number of reports	
	Number	Percent	Number	Percent	Number	Percent
Radiologists	12	2.7	425	97.3	437	100.0
Hospitals	97	3.8	2,431	96.2	2,528	100.0
Multiple specialty clinics	4	1.6	250	98.4	254	100.0
Internists	4	1.0	396	99.0	400	100.0
General practitioners in:						
Clinics	9	3.1	285	96.9	294	100.0
Private practice	48	2.6	1,779	97.4	1,827	100.0
Osteopaths	8	4.7	162	95.3	170	100.0
Chiropractors	88	12.6	610	87.4	698	100.0
All others	75	6.0	1,173	94.0	1,248	100.0
All facilities	345	4.4	7,515	95.6	7,860	100.0

Table 20. Beam diameter as reported for 14- by 17-inch film used with circular collimation by fiscal year periods (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Beam diameter	Fiscal year periods							
	1963–1964		1965–1966		1967–1968		All periods	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
16 inches or less (*2*)	42	5.0	171	3.7	131	5.5	344	4.4
Greater than 16 inches	805	95.0	4,449	96.3	2,250	94.5	7,504	95.6
Total	847	100.0	4,620	100.0	2,381	100.0	7,848	100.0

provided for the patient and operator in these facilities than in the other types of facilities. Internists and general practitioners as a group present the opposite picture insofar as radiation safety is measured by the factors considered in this report. It would appear that more effort with these particular user categories with regard to equipment and accessory shielding recommendations is required.

Distribution of fluoroscopic procedure reports by body area of examination and by type of machine

Table 22 shows that approximately 13 percent of the fluoroscopic examinations in this sample were performed on vertical fluoroscopic equipment. Such equipment is largely found in the offices of general practitioners and internists.

Table 21. Distribution of fluoroscopic procedure reports by body area of examination and by type of facility (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Type of facility	Body area of examination					
	Chest[a]		Gastrointestinal		Total	
	Number	Percent	Number	Percent	Number	Percent
Radiologists	142	10.1	638	16.0	780	14.5
Hospitals	433	30.9	2,215	55.6	2,648	49.2
Multiple speciality clinics	65	4.6	131	3.3	196	3.6
Internists	304	21.6	225	5.6	529	9.8
General practitioners	316	22.5	509	12.8	825	15.3
All other facilities	144	10.3	266	6.7	410	7.6
Total number of reports	1,404	100.0	3,984	100.0	5,388	100.0

[a] Data available from "old" fluoroscopic form, PHS-4495-2 only.

Table 22. Distribution of fluoroscopic procedure reports by body area of examination and by type of machine (Medical X-ray Protection Survey Reports, fiscal year 1963–1968)

Type of fluoroscopic machine	Body area of examination					
	Chest[a]		Gastrointestinal		Total	
	Number	Percent	Number	Percent	Number	Percent
Vertical table	453	32.3	240	6.0	693	12.9
Tilting table (includes horizontal)	918	65.4	3,728	93.6	4,646	86.2
Other	33	2.3	16	.4	49	.9
Total number of reports	1,404	100.0	3,984	100.0	5,388	100.0

[a] Data available from "old" fluoroscopic form, PHS-4495-2 only.

Percent distribution of operating factors reported for fluoroscopic examinations by body area of examination

Table 23 shows the wide range of operating factors that were reported for the respective examinations. This can be partially accounted for by the use of image intensification devices, poor dark adaptation, the age of the fluoroscopic screen (since the screens deteriorate with age), source-to-panel distance, and the lighttightness of the room.

Figures 1 through 5 are graphic presentations of the radiographic procedure parameter data shown in tables 12 through 16, omitting the category "Unknown." The characteristics of radiographic technique which are more predominant for one body area of examination than for another become more evident, although the wide variation in technique parameters remains the dominant feature.

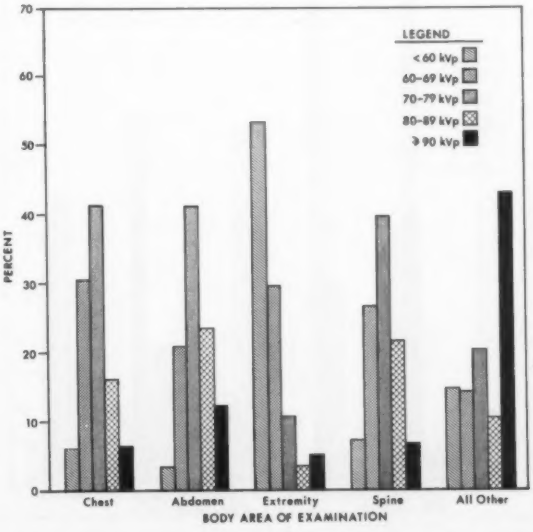

Figure 1. Percent distribution of kilovolt peak reported for radiographic procedures by body area of examination

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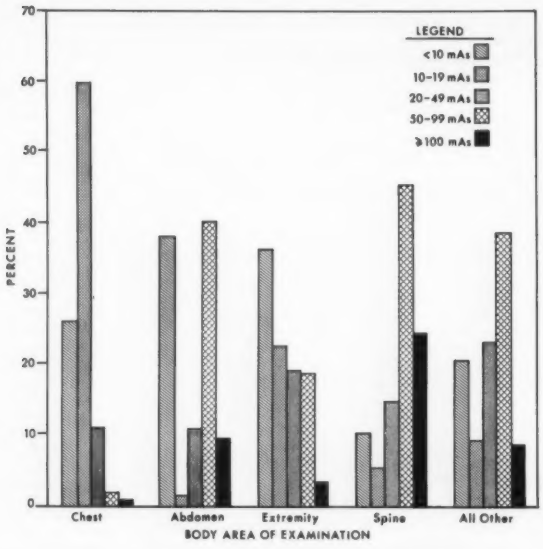

Figure 2. Percent distribution of milliamp-seconds reported for radiographic procedures by body area of examination

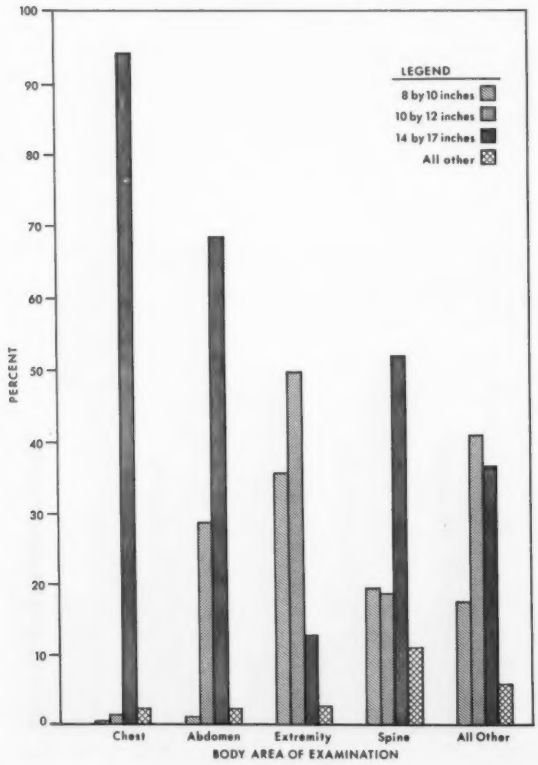

Figure 3. Percent distribution of film sizes reported as used for radiographic procedures by body area of examination

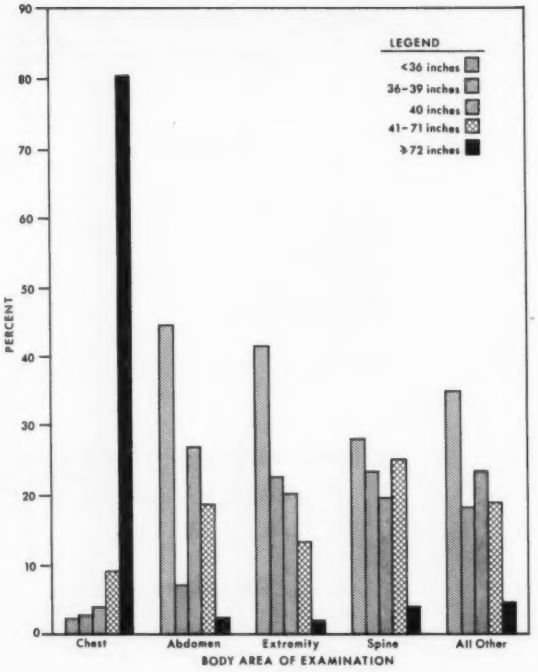

Figure 4. Percent distribution of source to film distance reported for radiographic procedures by body area of examination

Figures 6 and 7 are graphic presentations of the radiographic collimation data contained in tables 17 and 18, omitting the category "Unknown". As seen in figure 6, the need for improvement in collimation is evident when one compares the "improper collimation" bar to the "proper collimation" bar for each of the four major body areas of radiographic examination. It can also be seen in figure 7 that despite improvement in collimation status over the time period of this report, there remains even in the most recent period of fiscal year 1967 and 1968, a large proportion of procedures for which the beam size is excessive for the size of the film used. Figures 8, 9, and 10 are graphic presentations of the fluoroscopic procedure parameter data contained in tables 21, 22, and 23. They indicate the variation in technique parameters within and between chest and gastrointestinal tract examinations more readily than do the tables of numbers.

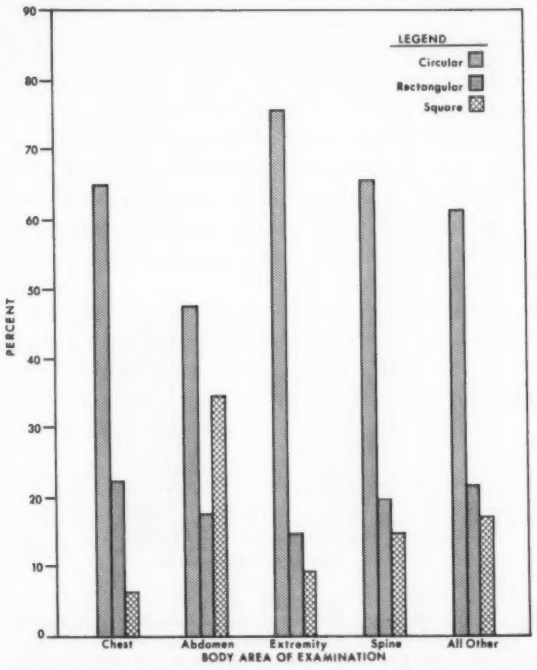

Figure 5. Percent distribution of beam shape reported for radiographic procedures by body area of examination

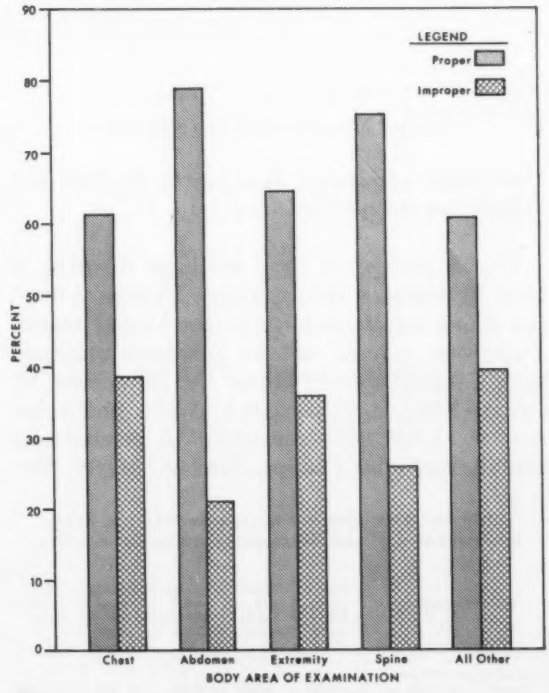

Figure 6. Collimation as reported by surveyor for radiographic procedures by body area of examination

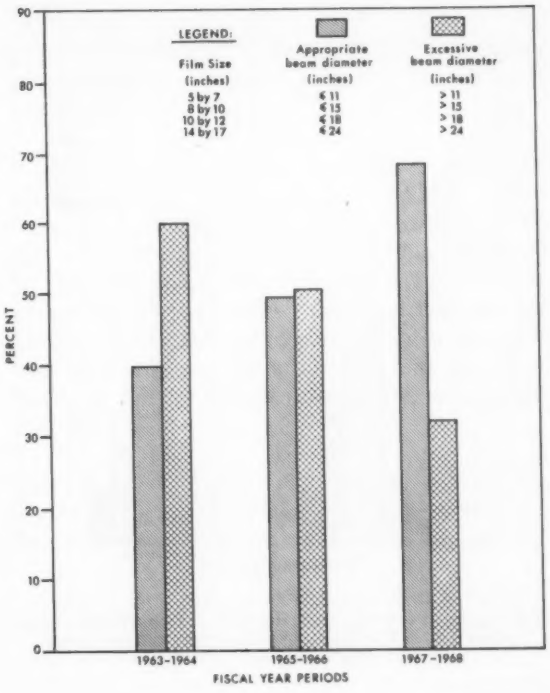

Figure 7. Collimation as determined from beam diameter and film size for radiographic procedures by fiscal year periods

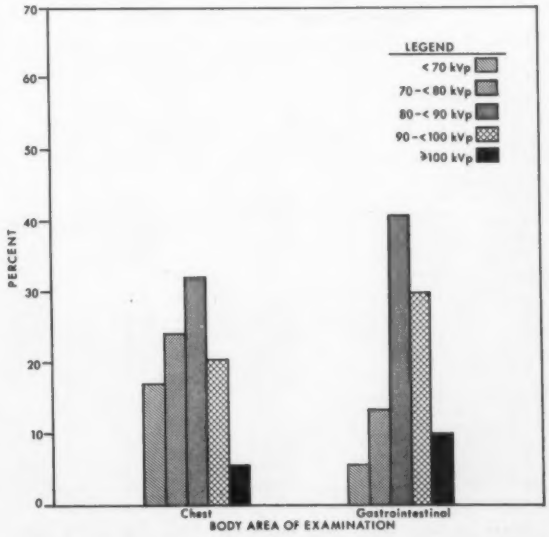

Figure 8. Percent distribution of kilovolt peak reported for fluoroscopic procedures by body area of examination

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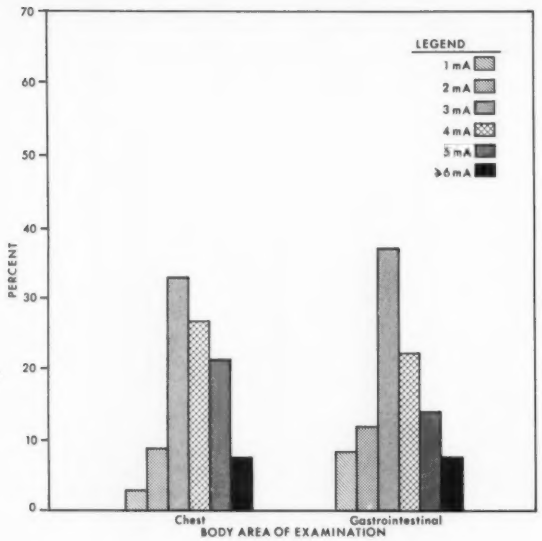

Figure 9. Percent distribution of milliamperage reported for fluoroscopic procedures by body area of examination

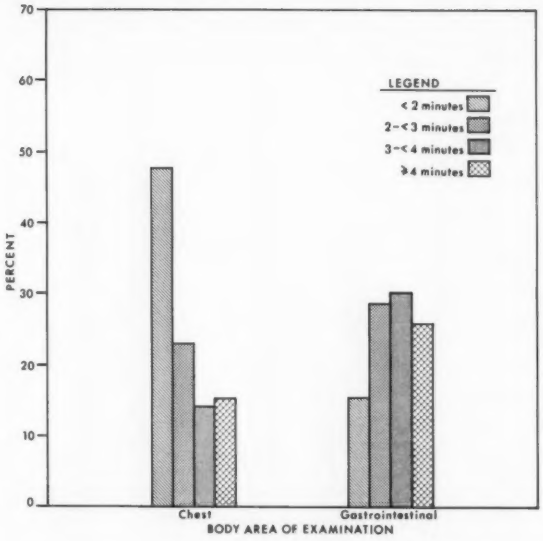

Figure 10. Percent distribution of number of minutes tube is activated per examination as reported for fluoroscopic procedures by body area of examination

Table 23. Percent distribution of operating factors reported for fluoroscopic examinations by body area of examination (Medical X-ray Protection Survey Reports, fiscal years 1963–1968)

Operating factor	Body area of examination (Percent)		
	Chest[a] (N=1,404)	Gastrointestinal (N=3,984)	Total (N=5,388)
Kilovolt peak:			
Less than 70	17.2	5.8	8.9
70–79	24.3	13.5	16.4
80–89	32.1	40.7	38.4
90–99	20.6	29.8	27.3
100 and over	5.8	10.2	9.0
Milliamperage:[b]			
1	3.0	8.2	6.7
2	8.9	11.7	10.9
3	32.8	36.8	35.6
4	26.5	22.0	23.2
5	21.3	13.8	15.9
6 or more	7.5	7.5	7.5
Number of minutes tube is activated per examination:[c]			
Less than 2	47.5	15.5	23.8
2 to 3	23.0	28.6	27.2
3 to 4	14.2	30.1	25.9
4 or more	15.3	25.8	23.1

[a] Data available from "old" fluoroscopic form, PHS-4495-2 only.
[b] Average milliamperage for chest examinations is 3.9; for gastrointestinal, 3.6.
[c] Average number of minutes tube is activated for chest examination is 2.0; for gastrointestinal, 2.9.

Dental X-ray Protection Surveys

Distribution of reported dental x-ray facilities and of machines surveyed by fiscal years

The 26,104 dental x-ray machines reported in table 24 represent approximately 25 percent of all the dental x-ray machines in the United States. Thirty-one percent of the surveyed machines were manufactured by Ritter Co., 30 percent by General Electric, 21 percent by Weber and 8 percent by XRM. The remaining 10 percent were manufactured by Phillips, Fischer, Meyer, Sie-

Table 24. Distribution of reported dental x-ray facilities and of machines surveyed by fiscal years

Subject of survey	Fiscal years 1961–1962	Fiscal years 1963–1964	Fiscal years 1965–1966	Fiscal years 1967–1968	All fiscal years
Dental x-ray facilities: Number surveyed	5,058	7,504	4,677	3,825	21,064
Dental x-ray machines: Number surveyed	5,960	8,988	6,004	5,152	26,104

mens, and others. Ninety percent of the machines surveyed were used by general practitioners; 3 percent by oral surgeons; 3 percent by orthodontists; and 4 percent by other dental specialists.

In this table the fiscal year survey data have been grouped into 2-year intervals in order to put more significant numbers into each category. This format is followed throughout the remaining tables.

The following tables vary in the numbers of facilities and machines reported. This is because the "error," "not stated," "not applicable," and "unknown" categories vary from item to item on the survey reports.

Percent distribution of dental x-ray facilities by reported number of x-ray machines and by fiscal years

Table 25 indicates that the number of x-ray machines per facility is increasing. In the last fiscal-year group surveyed, 27 percent of the facilities had two x-ray machines and 7 percent had three or more machines. This contrasts with the first fiscal year group, which had 15 percent and 3 percent, respectively.

Percent distribution of dental x-ray facilities by reported number of dental personnel and by fiscal years

Ninety percent of dental facilities with full-time dentists are one-man offices (table 26). There appears to be a tendency in the direction of two (or more) man offices. From the 1961–62 period to the 1967–68 period, there was a 2 percent increase in "two or more" full-time dentists per facility. The same trend can be noted in the 3 percent increase in the number of part-time dentists per facility in the total period covered by this report.

Percent distribution of dental x-ray facilities by reported number of ancillary dental personnel and by fiscal years

Twenty-one percent of the facilities were without any full-time dental ancillaries (table 27). This percentage remained almost constant for the entire report period. However, as the category "one full-time ancillary" decreased from 56 percent to 50 percent, the categories "two" and "three-or-more ancillaries" increased. There is

Table 25. Percent distribution of dental x-ray facilities by reported number of x-ray machines and by fiscal years

Reported number of x-ray machines per facility	Percent				
	Fiscal years 1961–1962 (N=5,058)	Fiscal years 1963–1964 (N=7,504)	Fiscal years 1965–1966 (N=4,677)	Fiscal years 1967–1968 (N=3,825)	All fiscal years (N=21,064)
One	82	82	74	66	77
Two	15	15	21	27	19
Three or more	3	3	5	7	4

Table 26. Percent distribution of dental x-ray facilities by reported number of dental personnel and by fiscal years

Reported number of personnel	Percent				
	Fiscal years 1961–1962	Fiscal years 1963–1964	Fiscal years 1965–1966	Fiscal years 1967–1968	All fiscal years
Dentists—full-time:	(N=5,025)	(N=7,457)	(N=4,648)	(N=3,805)	(N=20,935)
None	2	2	2	3	2
One	91	90	89	88	90
Two or more	7	8	9	9	8
Average number of full-time dentists per facility	1.08	1.08	1.10	1.09	1.09
Dentists—part-time:	(N=4,953)	(N=7,393)	(N=4,641)	(N=3,801)	(N=20,788)
None	96	95	95	93	95
One or more	4	5	5	7	5
Average number of part-time dentists per facility	0.06	0.07	0.08	0.10	0.08

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Table 27. Percent distribution of dental x-ray facilities by reported number of ancillary dental personnel and by fiscal years

Reported number of personnel	Percent				
	Fiscal years 1961–1962	Fiscal years 1963–1964	Fiscal years 1965–1966	Fiscal years 1967–1968	All fiscal years
Ancillaries—full-time:	(N=5,005)	(N=7,412)	(N=4,640)	(N=3,804)	(N=20,861)
None	21	22	21	21	21
One	56	54	50	50	53
Two	17	16	20	19	18
Three or more	6	8	9	10	8
Average number of full-time ancillaries per facility	1.14	1.15	1.23	1.24	1.18
Ancillaries—part-time:	(N=4,948)	(N=7,383)	(N=4,638)	(N=3,800)	(N=20,769)
None	85	83	77	79	81
One	14	14	18	16	15
Two or more	1	3	5	5	4
Average number of part-time ancillaries per facility	0.18	0.21	0.30	0.29	0.24

also a slight increase in the use of part-time ancillaries.

Percent distribution of occupationally exposed personnel in dental facilities

Table 28 points out that 48 percent of full-time dental office personnel are dentists. In the part-time category, only 24 percent are dentists. There is an average of 2.6 occupationally exposed persons per facility of which more are dental ancillaries than dentists. Eighteen percent of the 21,064 dental facilities surveyed reported that they use or had used some form of personnel monitoring. Of these, 51 percent used standard film badges, 44 percent used dental films, 4 percent used pocket dosimeters, and 1 percent used pocket chambers or other devices. However, only 3 percent of the total dental facilities reported using any kind of personnel monitor *at the time of the survey.*

Table 28. Percent distribution of occupationally exposed personnel in dental facilities

Occupation	Employment status of personnel (percent)		
	Full-time (N=47,389)	Part-time (N=6,478)	All personnel (N=53,867)
Dentists	48	24	45
Ancillaries	52	76	55

Percent distribution of dental x-ray machines by beam diameter and by fiscal years

The data in table 29 indicate that proper collimation of the machines surveyed has largely been accomplished. Even before modification of the machines only 7 percent of the machines surveyed in the fiscal years 1967 and 1968 had a beam diameter greater than the 3 inches recommended as an upper limit in NBS Handbook 76.

Table 29. Percent distribution of dental x-ray machines by beam diameter and by fiscal years

Beam diameter (inches)	Percent				
	Fiscal years 1961–1962	Fiscal years 1963–1964	Fiscal years 1965–1966	Fiscal years 1967–1968	All fiscal years
Before modification:	(N=5,887)	(N=8,857)	(N=5,962)	(N=5,004)	(N=25,710)
2.75 or less	50	55	70	86	64
2.76 to 3.00	14	18	20	7	15
3.01 or greater	36	27	10	7	21
After modification:[a]	(N=5,227)	(N=8,420)	(N=5,888)	(N=4,859)	(N=24,394)
2.75 or less	81	77	77	91	81
2.76 to 3.00	18	21	22	8	18
3.01 or greater	1	2	1	1	1

[a] On-the-spot modification at the time of the survey.

In fiscal years 1961 and 1962, 36 percent had a beam diameter greater than 3 inches before modification. The continual upgrading of collimation throughout the 8-year period is evident. After modification of the machines in fiscal years 1967 and 1968, only 1 percent of the machines exceeded the 3-inch limit and 91 percent had a beam diameter of 2.75 inches or less as recommended by the American Academy of Dental Radiology (*3*).

Collimation status of selected dental x-ray machine models before and after modification of beam diameter

Table 30 presents collimation data on some early dental x-ray machines which originally exhibited excessive beam diameters. Before modification, 39 percent had beam diameters in excess of 3 inches. After modification, only 1 percent had beam diameters in excess of 3 inches demonstrating that even older models of x-ray machines can be modified to meet this recommended standard.

Table 30. Collimation status of selected dental x-ray machine models before and after modification of beam diameter

Model of dental x-ray machine	Collimation status				Total number of machines surveyed
	Machines having beam diameter greater than 3 inches				
	Before modification		After modification[a]		
	Number	Percent	Number	Percent	
Ritter A	114	50	11	5	229
Ritter B	1,845	43	26	1	4,283
Ritter D	671	39	11	1	1,742
Weber 5	64	36	0	0	176
Weber 6	535	54	8	1	996
Weber 6A	218	32	6	1	677
Weber Radex 70	133	24	6	1	562
XRM 2A	85	31	7	3	277
XRM 3A	148	30	18	4	494
XRM 90	99	15	13	2	670
Fischer	142	38	12	3	378
Summary	4,054	39	118	1	10,484

[a] On-the-spot modification at the time of the survey.

Percent distribution of dental x-ray machines by total filtration in millimeters of aluminum equivalent and by fiscal years

State filtration requirements vary somewhat, but those of NBS Handbook 76 are the most widely accepted. All of the States in this report recommended or required the Handbook 76 figure of at least 1.5 mm. of aluminum equivalent.

In the first fiscal year group of this report, 47 percent of the machines had less than the recommended 1.5 mm of aluminum equivalent before modification (table 31). In fiscal years 1967 and 1968, only 2 percent of the machines did not have at least 1.5 mm aluminum equivalent after modification.

Percent distribution of dental x-ray machines by roentgen output at the cone tip and by fiscal years

Table 32 reflects the results of modifying the filtration of the x-ray machine over the reporting period. With increased filtration, roentgen output is reduced since most of the unnecessary "soft" x-rays are filtered out. In the fiscal year group 1961 and 1962, 21 percent of the machines surveyed had an exposure rate of more than 2.5 R/s before modification, compared to only 6 percent of the machines in fiscal year group 1967 and 1968. At the same time the proportion of machines delivering 1.0 R/s or less increased from 27 percent to 49 percent. After modification, 53

Table 31. Percent distribution of dental x-ray machines by total filtration in millimeters of aluminum equivalent and by fiscal years

Total filtration (mm of Al equivalent)	Percent				
	Fiscal years 1961–1962	Fiscal years 1963–1964	Fiscal years 1965–1966	Fiscal years 1967–1968	All fiscal years
Before modification:	(N=5,848)	(N=8,844)	(N=5,923)	(N=4,986)	(N=25,601)
Less than 1.5	47	36	17	8	29
1.5 to 2.4	43	51	62	62	54
2.5 or greater	10	13	21	30	17
After modification:[a]	(N=5,358)	(N=8,494)	(N=5,868)	(N=4,909)	(N=24,629)
Less than 1.5	3	3	2	2	3
1.5 to 2.4	85	79	69	65	75
2.5 or greater	12	18	29	33	22

[a] On-the-spot modification to meet recommendations at the time of the survey.

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Table 32. Percent distribution of dental x-ray machines by roentgen output at the cone tip and by fiscal years

Roentgen output at cone tip (R/s)	Percent				
	Fiscal years 1961–1962	Fiscal years 1963–1964	Fiscal years 1965–1966	Fiscal years 1967–1968	All fiscal years
Before modification:	(N = 3,146)	(N = 3,297)	(N = 2,878)	(N = 2,773)	(N = 12,094)
1.00 or less	27	36	46	49	39
1.01 to 2.50	52	51	48	45	49
2.51 or more	21	13	6	6	12
After modification:[a]	(N = 2,874)	(N = 3,290)	(N = 2,941)	(N = 2,716)	(N = 11,821)
1.00 or less	59	65	54	53	58
1.01 to 2.50	38	33	43	43	39
2.51 or more	3	2	3	4	3

[a] On-the-spot modification to meet recommendations at the time of the survey.

Table 33. Percent distribution of dental x-ray machines by estimated workload in milliampere-seconds per week and by fiscal years

Estimated workload in mAs per week per machine	Percent				
	Fiscal years 1961–1962 (N = 5,716)	Fiscal years 1963–1964 (N = 8,639)	Fiscal years 1965–1966 (N = 5,842)	Fiscal years 1967–1968 (N = 4,841)	All fiscal years (N = 25,038)
300 or less	41	47	47	58	48
301 to 600	25	24	25	22	24
601 to 900	14	12	12	9	12
901 or more	20	17	16	11	16

Table 34. Percent distribution of dental x-ray machines by cone type and by fiscal years

Cone type	Percent				
	Fiscal years 1961–1962 (N = 5,825)	Fiscal years 1963–1964 (N = 8,773)	Fiscal years 1965–1966 (N = 5,902)	Fiscal years 1967–1968 (N = 5,085)	All fiscal years (N = 25,585)
Pointed	92	93	89	89	91
Open	8	8	11	11	9

Table 35. Percent distribution of dental x-ray machines by type of timer and by fiscal years

Type of timer	Percent				
	Fiscal years 1961–1962 (N = 5,880)	Fiscal years 1963–1964 (N = 8,863)	Fiscal years 1965–1966 (N = 5,989)	Fiscal years 1967–1968 (N = 5,047)	All fiscal years (N = 25,779)
Mechanical	71	65	57	51	62
Electrical or electronic	29	35	43	49	38

Table 36. Percent distribution of dental x-ray machines by distance operable from tube head and by fiscal years

Distance operable from tube head	Percent				
	Fiscal years 1961–1962 (N = 5,878)	Fiscal years 1963–1964 (N = 8,903)	Fiscal years 1965–1966 (N = 5,992)	Fiscal years 1967–1968 (N = 5,042)	All fiscal years (N = 25,815)
Less than 6 feet	14	11	6	3	9
6 feet or more	86	89	94	97	91

Table 37. Percent distribution of lead aprons by machine and by fiscal years

Lead apron	Percent				
	Fiscal years 1961–1962 (N = 5,881)	Fiscal years 1963–1964 (N = 8,841)	Fiscal years 1965–1966 (N = 5,884)	Fiscal years 1967–1968 (N = 5,026)	All fiscal years (N = 25,632)
Present	7	21	52	44	29
None[a]	93	79	48	56	71

[a] Includes category of "present but not used," 212 replies or less than one percent of total.

percent of the machines surveyed in fiscal year 1967–1968 produced 1 R/s or less.

Percent distribution of dental x-ray machines by estimated workloads in milliampere-seconds per week and by fiscal years

In table 33, a trend to a reduced workload per machine per week as estimated in milliampere seconds (mAs) per week is observed. This is undoubtedly due to the increased use of faster film as shown in table 38. Otherwise, one would expect a higher mAs workload per machine since the number of films per week per machine as noted in table 39 increased during the period covered by this report.

Percent distribution of dental x-ray machines by cone type and by fiscal years

Table 34 shows that 91 percent of the total dental x-ray machines surveyed were equipped with pointed cones. The remainder were fitted with open cones which are more desirable because there is no plastic material intercepting the useful beam.

Percent distribution of dental x-ray machines by type of timer and by fiscal years

In fiscal years 1967 and 1968, 49 percent of the machines surveyed had electronic timers. Only 29 percent of the machines had electronic timers in fiscal years 1961 and 1962. This trend, shown in table 35, reflects the increasing number of new machines being surveyed, almost all of which are equipped with electrical or electronic timers. In addition, many older x-ray machines have had electronic or electrical timers installed to replace the mechanical timers.

Percent distribution of dental x-ray machines by distance operable from tube head and by fiscal years

Table 36 shows that 97 percent of the machines in the latest fiscal year grouping had the operator position at least 6 feet from the tube head when the tube head is in position to radiograph the patient as recommended in NBS Handbook 76. This is an improvement over the 86 percent figure recorded for the first fiscal year grouping.

Percent distribution of lead aprons per machine by fiscal years

Table 37 shows that there is a trend to the increased use of leaded aprons for gonadal shielding in dental offices. Forty-four percent in the 1967–1968 fiscal year group were equipped with leaded aprons compared with only 7 percent so equipped in the fiscal year 1961–1962 grouping.

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Table 38. Percent distribution of dental x-ray facilities by reported film speed of bite-wing and of periapical film and by fiscal years

Film speed group[a]	Percent				
	Fiscal years 1961–1962	Fiscal years 1963–1964	Fiscal years 1965–1966	Fiscal years 1967–1968	All fiscal years
Bite-wing:	(N=4,227)	(N=6,504)	(N=4,203)	(N=2,082)	(N=17,916)
A	6	3	1	1	3
B	50	48	35	29	42
C	21	17	18	13	18
D	23	32	46	57	37
Periapical:	(N=4,117)	(N=6,463)	(N=3,882)	(N=2,687)	(N=17,149)
A	5	3	1	1	3
B	49	47	34	30	42
C	21	18	19	14	18
D	25	32	46	55	37

[a] American National Standards Institute speed classifications for intraoral dental radiographic film (4).

Speed group	Speed range (In reciprocal roentgens)
A	1.5– 3.0
B	3.0– 6.0
C	6.0–12.0
D	12.0–24.0

Table 39. Percent distribution of dental x-ray machines by average number of films per week per machine and by fiscal years

Average number of films per week per machine	Percent				
	Fiscal years 1961–1962 (N=5,838)	Fiscal years 1963–1964 (N=8,769)	Fiscal years 1965–1966 (N=5,910)	Fiscal years 1967–1968 (N=4,978)	All fiscal years (N=25,495)
Less than 20	19	19	14	17	17
20–39	27	27	21	22	25
40–59	22	23	24	25	23
60–79	14	12	16	15	14
80 or more	18	19	25	21	21

Percent distribution of dental x-ray facilities by reported film speed of bitewing and of periapical film and by fiscal years

Table 38 indicates the increased use of fast film (Speed-Group D). Little difference in film speed can be noted between the reported use of periapical and bite-wing film by film speed; that is, those offices using speed-group D bite-wing film also used speed-group D periapical film.

Percent distribution of dental x-ray machines by average number of films per week per machine and by fiscal years

Table 39 indicates an increase in workload from the standpoint of the number of films used per machine per week since fiscal years 1961 and 1962.

Percent distribution of dental facilities by presence and use of thermometer and by fiscal years

Before fiscal year 1965, the presence of a thermometer in the darkroom was reported in 70 percent of the facilities (table 40). By fiscal years 1967–1968, the presence of a thermometer in the darkroom had increased to 78 percent, a slight improvement.

Percent distribution of dental facilities by developer temperature[2] and by fiscal years

Ninety-five percent of the dental facilities reported developing dental x-ray films at temperatures of 64° F. through 75° F., (table 41). There

[2] Developer temperature—temperature reported by the dentist.

has been little change over the years covered by this report.

There is little agreement among dental x-ray film manufacturers regarding a standard time and temperature for film development. However, the 64° F. to 75° F. interval seems to cover the temperature recommendations of the major dental film manufacturers. Within this temperature range, the time of development should be from 3.5 to 7 minutes.

Percent distribution of dental x-ray facilities by x-ray film development time and by fiscal years

Although table 41 indicated that 95 percent of the facilities are developing film between 64° F. and 75° F., less than 40 percent are using 3.5 minutes or more to develop (table 42). This is significant because the time of development is directly related to the temperature of the developing solution. Referring to the tables on developer temperature and development time, one can note that film underdevelopment appears to be common in dentistry. This underdevelopment is undoubtedly accompanied by film (and patient) overexposure in order to achieve a desirable film density. There is only slight improvement over the time period covered by this report. Fiscal years 1967 and 1968 show that 41 percent of the facilities developed their films for 3.5 or more minutes, whereas only 31 percent of the facilities did so in fiscal years 1961 and 1962.

Percent distribution of dental facilities by reported time period for change of developer and by fiscal years

In table 43, there is a very slight indication of an increase in the frequency with which developing solutions are changed in dental facilities. This may be accounted for by the greater workload as evidenced by the number of films being used per week per machine, and by the increase in the number of machines per facility over the period of this report.

Percent distribution of dental facilities by lighttightness of darkroom and by fiscal years

For all fiscal years, 24 percent of the darkrooms surveyed were reported as not lighttight (table 44). The criterion of lighttightness depended on subjective determinations made by the various State surveyors. Some improvement can be noted over this report period inasmuch as lighttightness in-

Table 40. Percent distribution of dental facilities by presence and use of therometer and by fiscal years

Developer-thermometer	Percent				
	Fiscal years 1961–1962 (N=4,530)	Fiscal years 1963–1964 (N=7,130)	Fiscal years 1965–1966 (N=4,411)	Fiscal years 1967–1968 (N=3,570)	All fiscal years (N=19,641)
Not present	27	28	22	21	25
Present	70	70	77	78	73
Thermostatic control	2	1	<1	1	1
No darkroom	<1	<1	<1	<1	<1
Present, not used	<1	<1	<1	<1	<1

Table 41. Percent distribution of dental facilities by developer temperature and by fiscal years

Developer temperature[a]	Percent				
	Fiscal years 1961–1962 (N=3,640)	Fiscal years 1963–1964 (N=6,171)	Fiscal years 1965–1966 (N=3,719)	Fiscal years 1967–1968 (N=3,025)	All fiscal years (N=16,555)
<60°F.	1	<1	<1	<1	<1
61°F.–63°F.	<1	<1	<1	<1	<1
64°F.–66°F.	9	5	4	4	5
67°F.–69°F.	42	39	41	40	40
70°F.–72°F.	36	40	44	47	41
73°F.–75°F.	8	11	7	5	9
>75°F.	4	3	2	3	3

[a] Developer temperature-temperature reported by the dentist.

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Table 42. Percent distribution of dental x-ray facilities by x-ray film development time and by fiscal years

Development time (minutes)	Percent				
	Fiscal years 1961–1962 (N=4,515)	Fiscal years 1963–1964 (N=7,095)	Fiscal years 1965–1966 (N=4,401)	Fiscal years 1967–1968 (N=3,173)	All fiscal years (N=19,184)
Less than 2.5[a]	36	29	28	28	30
2.5 to 3.4	33	34	26	31	32
3.5 to 4.4	17	21	20	21	20
4.5 or more	14	16	26	20	18

[a] Includes 742 or 4 percent which were reported as sight developing which is undesirable because of the imprecision of the method and possible film fogging due to exposure to white light.

Table 43. Percent distribution of dental facilities by reported time period for change of developer and by fiscal years

Developer change period	Percent				
	Fiscal years 1961–1962 (N=4,390)	Fiscal years 1963–1964 (N=6,767)	Fiscal years 1965–1966 (N=4,296)	Fiscal years 1967–1968 (N=3,099)	All fiscal years (N=18,552)
<2 weeks	5	4	4	6	4
2 to 4 weeks	68	69	74	70	70
4 to 6 weeks	11	11	10	11	11
6 to 8 weeks	10	9	7	9	9
>8 weeks	6	7	5	4	6

Table 44. Percent distribution of dental facilities by lighttightness of darkroom and by fiscal years

Lighttightness	Percent				
	Fiscal years 1961–1962 (N=4,509)	Fiscal years 1963–1964 (N=7,039)	Fiscal years 1965–1966 (N=4,357)	Fiscal years 1967–1968 (N=3,525)	All fiscal years (N=19,430)
Lighttight	69	74	81	85	76
Not lighttight	31	26	19	15	24

creased from 69 percent in the fiscal year period of 1961–1962, to 85 percent by the fiscal year period, 1967–1968.

Percent distribution of dental x-ray machines meeting recommendations as specified in NBS Handbook 76 (1) and by fiscal years

Table 45 indicates that the three items specifically mentioned in NBS Handbook 76 (i.e.,distance limitation at which machine is operable, filtration, and collimation) were never overwhelming problems. It should be noted, however, that the collimation and filtration data reflect onsite modifications made by the surveyor.

The greatest area for future reduction of unnecessary dental x-ray exposure is in the technique and judgment area. This requires that the dentist be educated and motivated to take only those films necessary for proper diagnosis, to use the fastest film available, to develop the films properly in a suitable darkroom, and to interpret them with the aid of proper equipment. At the same time he should continue to improve his diagnostic acumen through continuing education whether through formal courses and seminars or through his professional readings.

Table 45. Percent distribution of dental x-ray machines meeting recommendations as specified in NBS Handbook 76(*1*) and by fiscal years

Recommendations	Fiscal years 1961–1962	Fiscal years 1963–1964	Fiscal years 1965–1966	Fiscal years 1967–1968	All fiscal years
Machine operable 6 feet or more from tube head:					
Number of machines surveyed	5,878	8,903	5,992	5,042	25,815
Percent in compliance	86	89	94	97	91
Filtration 1.5 mm of Al equivalent or more after modification:[a]					
Number of machines surveyed	5,358	8,494	5,868	4,909	24,629
Percent in compliance	97	97	98	98	97
Beam diameter 3 inches or less after modification:[a]					
Number of machines surveyed	5,227	8,402	5,888	4,859	24,394
Percent in compliance	99	98	99	99	99

[a] On-the-spot modification to meet the recommendations at the time of the survey.

Conclusions and recommendations

The areas in which major efforts should be made are as follows:

Equipment: The high percentage of medical facilities have improper collimation, especially in view of the more recent recommendations appearing in NCRP Report No. 33, and inadequate filtration indicates that a major effort in these areas is still needed to correct equipment deficiencies. At the same time, the large proportion of facilities in which accessory patient or operator shielding was lacking or inadequate, together with the infrequent use of any personnel monitoring system, identifies additional areas that require attention by user groups and by radiation control programs. This is necessary in order to achieve further reduction of unnecessary radiation to the general population and occupationally exposed medical groups.

Although dental x-ray equipment does not appear to present as significant a population exposure problem as does medical equipment, the universal use of a shielded open-end aiming device, together with the use of Speed Group D film, would further reduce the radiation exposure to the patient and the operator. Related areas needing attention are primarily darkrooms and darkroom procedures which according to the information available in this report vary greatly in quality and preciseness.

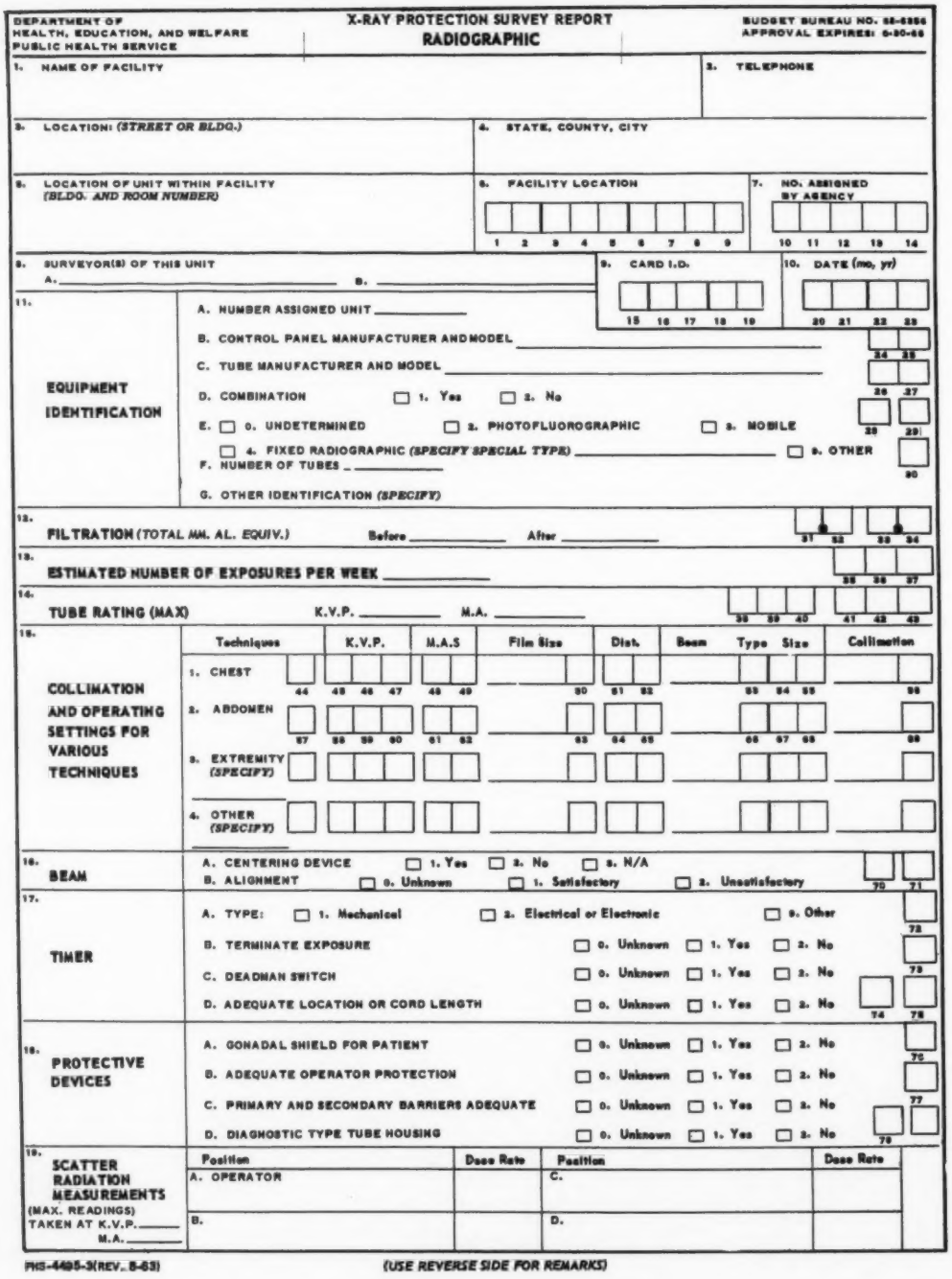
Standardization of survey techniques and data collection: The high percentage of "unknowns" in the data reported emphasize the need for the standardization of surveying techniques and for uniformity and comparability of data collected in State radiological health programs. Survey forms should also be revised using recent NCRP recommendations as a guide, and all data inquiries should be eliminated when they are of doubtful value in defining or assessing radiological health problems and progress.

Insofar as radiation exposure reduction can be affected by items peripheral to the x-ray equipment itself, such as film speed, darkroom procedures, and the like, inquiries should be added to the survey forms to provide State programs a practical basis for action in these areas.

Technique and judgment: A continuing effort aimed at improving the technique of the operator of the machine and the professional judgment of the practitioner requesting the examination is essential if the efforts toward dose reduction are to be successful. This could be accomplished in part if the use of gonadal shielding were as universal as is the presence of deadman-type switches on x-ray equipment. The use of fluoroscopy in cases where a radiograph would serve a more useful purpose, and inadequate beam collimation in facilities where adequate collimating devices are available, reinforce the conclusion that a continuing effort aimed at improving the technique of the machine operator and the professional judgment of the practitioner are required.

Acknowledgments

Thanks are gratefully conveyed to all participating States and their surveyors, and to



DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE

X-RAY PROTECTION SURVEY REPORT
RADIOGRAPHIC

BUDGET BUREAU NO. 68-R356
APPROVAL EXPIRES: 6-30-68

1. NAME OF FACILITY
2. TELEPHONE
3. LOCATION: (STREET OR BLDG.)
4. STATE, COUNTY, CITY
5. LOCATION OF UNIT WITHIN FACILITY (BLDG. AND ROOM NUMBER)
6. FACILITY LOCATION (1 2 3 4 5 6 7 8 9)
7. NO. ASSIGNED BY AGENCY (10 11 12 13 14)
8. SURVEYOR(S) OF THIS UNIT — A. _____ B. _____
9. CARD I.D. (15 16 17 18 19)
10. DATE (mo, yr) (20 21 22 23)

11. EQUIPMENT IDENTIFICATION
- A. NUMBER ASSIGNED UNIT _____
- B. CONTROL PANEL MANUFACTURER AND MODEL _____ (24 25)
- C. TUBE MANUFACTURER AND MODEL _____ (26 27)
- D. COMBINATION ☐ 1. Yes ☐ 2. No
- E. ☐ 0. UNDETERMINED ☐ 2. PHOTOFLUOROGRAPHIC ☐ 3. MOBILE ☐ 4. FIXED RADIOGRAPHIC (SPECIFY SPECIAL TYPE) _____ ☐ 5. OTHER (28 29)
- F. NUMBER OF TUBES _____ (30)
- G. OTHER IDENTIFICATION (SPECIFY)

12. FILTRATION (TOTAL MM. AL. EQUIV.) Before _____ After _____ (31 32 33 34)

13. ESTIMATED NUMBER OF EXPOSURES PER WEEK _____ (35 36 37)

14. TUBE RATING (MAX) K.V.P. _____ M.A. _____ (38 39 40 41 42 43)

15. COLLIMATION AND OPERATING SETTINGS FOR VARIOUS TECHNIQUES

Techniques	K.V.P.	M.A.S	Film Size	Dist.	Beam Type	Beam Size	Collimation
1. CHEST (44)	(45 46 47)	(48 49)	(50)	(51 52)	(53)	(54 55)	(56)
2. ABDOMEN (57)	(58 59 60)	(61 62)	(63)	(64 65)	(66)	(67 68)	(69)
3. EXTREMITY (SPECIFY)							
4. OTHER (SPECIFY)							

16. BEAM
- A. CENTERING DEVICE ☐ 1. Yes ☐ 2. No ☐ 3. N/A (70)
- B. ALIGNMENT ☐ 0. Unknown ☐ 1. Satisfactory ☐ 2. Unsatisfactory (71)

17. TIMER
- A. TYPE: ☐ 1. Mechanical ☐ 2. Electrical or Electronic ☐ 9. Other (72)
- B. TERMINATE EXPOSURE ☐ 0. Unknown ☐ 1. Yes ☐ 2. No (73)
- C. DEADMAN SWITCH ☐ 0. Unknown ☐ 1. Yes ☐ 2. No (74)
- D. ADEQUATE LOCATION OR CORD LENGTH ☐ 0. Unknown ☐ 1. Yes ☐ 2. No (75)

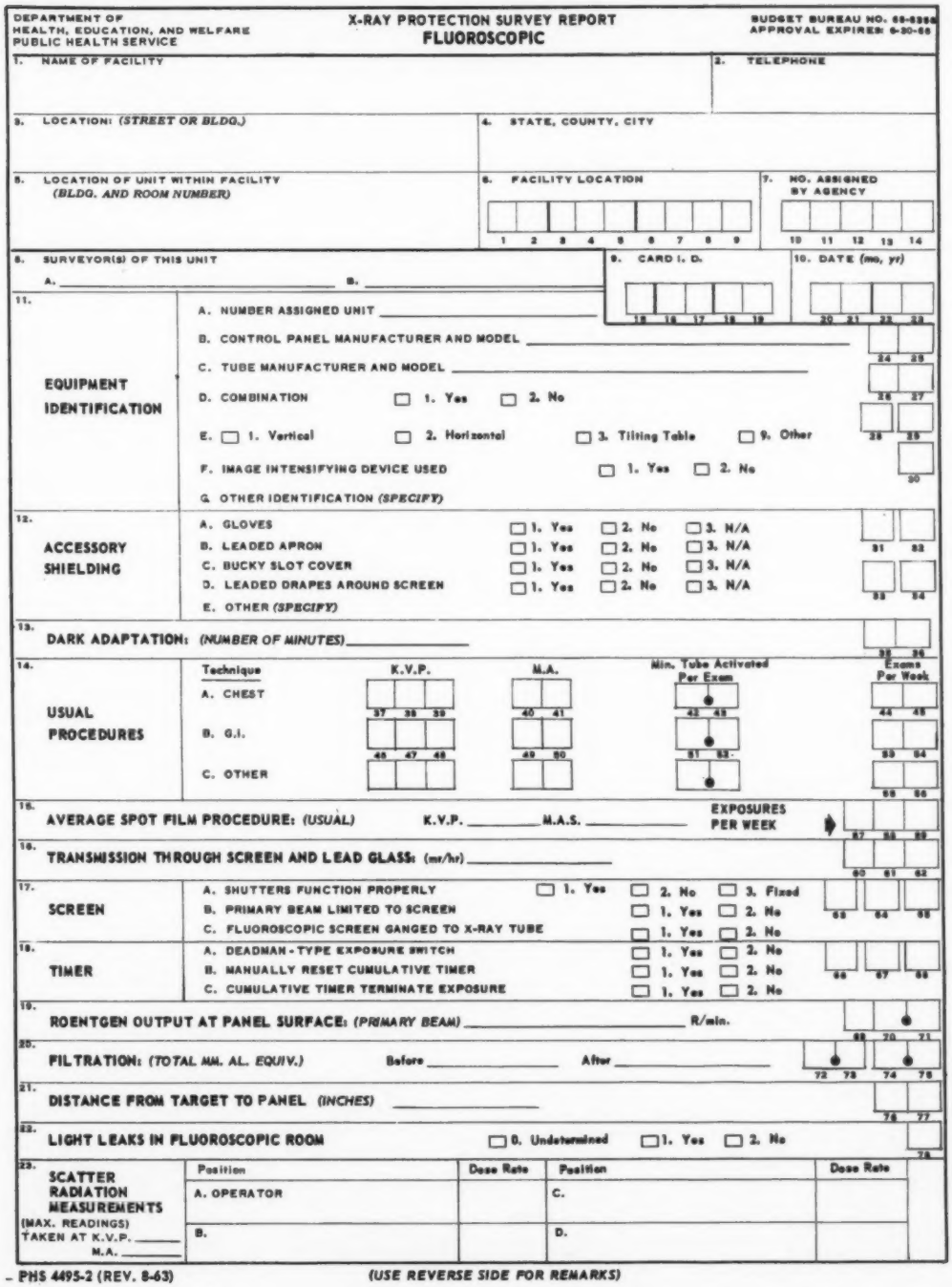
18. PROTECTIVE DEVICES
- A. GONADAL SHIELD FOR PATIENT ☐ 0. Unknown ☐ 1. Yes ☐ 2. No (76)
- B. ADEQUATE OPERATOR PROTECTION ☐ 0. Unknown ☐ 1. Yes ☐ 2. No (77)
- C. PRIMARY AND SECONDARY BARRIERS ADEQUATE ☐ 0. Unknown ☐ 1. Yes ☐ 2. No (78)
- D. DIAGNOSTIC TYPE TUBE HOUSING ☐ 0. Unknown ☐ 1. Yes ☐ 2. No (79)

19. SCATTER RADIATION MEASUREMENTS (MAX. READINGS) TAKEN AT K.V.P. _____ M.A. _____ (80)

Position	Dose Rate	Position	Dose Rate
A. OPERATOR		C.	
B.		D.	

PHS-4495-3(REV. 8-63) (USE REVERSE SIDE FOR REMARKS)

Figure 12. "Old" radiographic form—Medical X-ray Protection Survey Reports



DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE

X-RAY PROTECTION SURVEY REPORT
FLUOROSCOPIC

BUDGET BUREAU NO. 68-R356
APPROVAL EXPIRES: 6-30-65

1. NAME OF FACILITY
2. TELEPHONE
3. LOCATION: (STREET OR BLDG.)
4. STATE, COUNTY, CITY
5. LOCATION OF UNIT WITHIN FACILITY (BLDG. AND ROOM NUMBER)
6. FACILITY LOCATION (1 2 3 4 5 6 7 8 9)
7. NO. ASSIGNED BY AGENCY (10 11 12 13 14)
8. SURVEYOR(S) OF THIS UNIT — A. _____ B. _____
9. CARD I. D. (15 16 17 18 19)
10. DATE (mo, yr) (20 21 22 23)

11. EQUIPMENT IDENTIFICATION
- A. NUMBER ASSIGNED UNIT _____
- B. CONTROL PANEL MANUFACTURER AND MODEL _____ (24 25)
- C. TUBE MANUFACTURER AND MODEL _____ (26 27)
- D. COMBINATION ☐ 1. Yes ☐ 2. No (28)
- E. ☐ 1. Vertical ☐ 2. Horizontal ☐ 3. Tilting Table ☐ 9. Other (29)
- F. IMAGE INTENSIFYING DEVICE USED ☐ 1. Yes ☐ 2. No (30)
- G. OTHER IDENTIFICATION (SPECIFY)

12. ACCESSORY SHIELDING

A. GLOVES	☐ 1. Yes	☐ 2. No	☐ 3. N/A	(31)
B. LEADED APRON	☐ 1. Yes	☐ 2. No	☐ 3. N/A	(32)
C. BUCKY SLOT COVER	☐ 1. Yes	☐ 2. No	☐ 3. N/A	(33)
D. LEADED DRAPES AROUND SCREEN	☐ 1. Yes	☐ 2. No	☐ 3. N/A	(34)
E. OTHER (SPECIFY)				

13. DARK ADAPTATION: (NUMBER OF MINUTES) _____ (35 36)

14. USUAL PROCEDURES

Technique	K.V.P.	M.A.	Min. Tube Activated Per Exam	Exams Per Week
A. CHEST	(37 38 39)	(40 41)	(42 43)	(44 45)
B. G.I.	(46 47 48)	(49 50)	(51 52)	(53 54)
C. OTHER				(55 56)

15. AVERAGE SPOT FILM PROCEDURE: (USUAL) K.V.P. _____ M.A.S. _____ EXPOSURES PER WEEK (57 58 59)

16. TRANSMISSION THROUGH SCREEN AND LEAD GLASS: (mr/hr) _____ (60 61 62)

17. SCREEN
- A. SHUTTERS FUNCTION PROPERLY ☐ 1. Yes ☐ 2. No ☐ 3. Fixed (63)
- B. PRIMARY BEAM LIMITED TO SCREEN ☐ 1. Yes ☐ 2. No (64)
- C. FLUOROSCOPIC SCREEN GANGED TO X-RAY TUBE ☐ 1. Yes ☐ 2. No (65)

18. TIMER
- A. DEADMAN-TYPE EXPOSURE SWITCH ☐ 1. Yes ☐ 2. No (66)
- B. MANUALLY RESET CUMULATIVE TIMER ☐ 1. Yes ☐ 2. No (67)
- C. CUMULATIVE TIMER TERMINATE EXPOSURE ☐ 1. Yes ☐ 2. No (68)

19. ROENTGEN OUTPUT AT PANEL SURFACE: (PRIMARY BEAM) _____ R/min. (69 70 71)

20. FILTRATION: (TOTAL MM. AL. EQUIV.) Before _____ After _____ (72 73 74 75)

21. DISTANCE FROM TARGET TO PANEL (INCHES) _____ (76 77)

22. LIGHT LEAKS IN FLUOROSCOPIC ROOM ☐ 0. Undetermined ☐ 1. Yes ☐ 2. No (78)

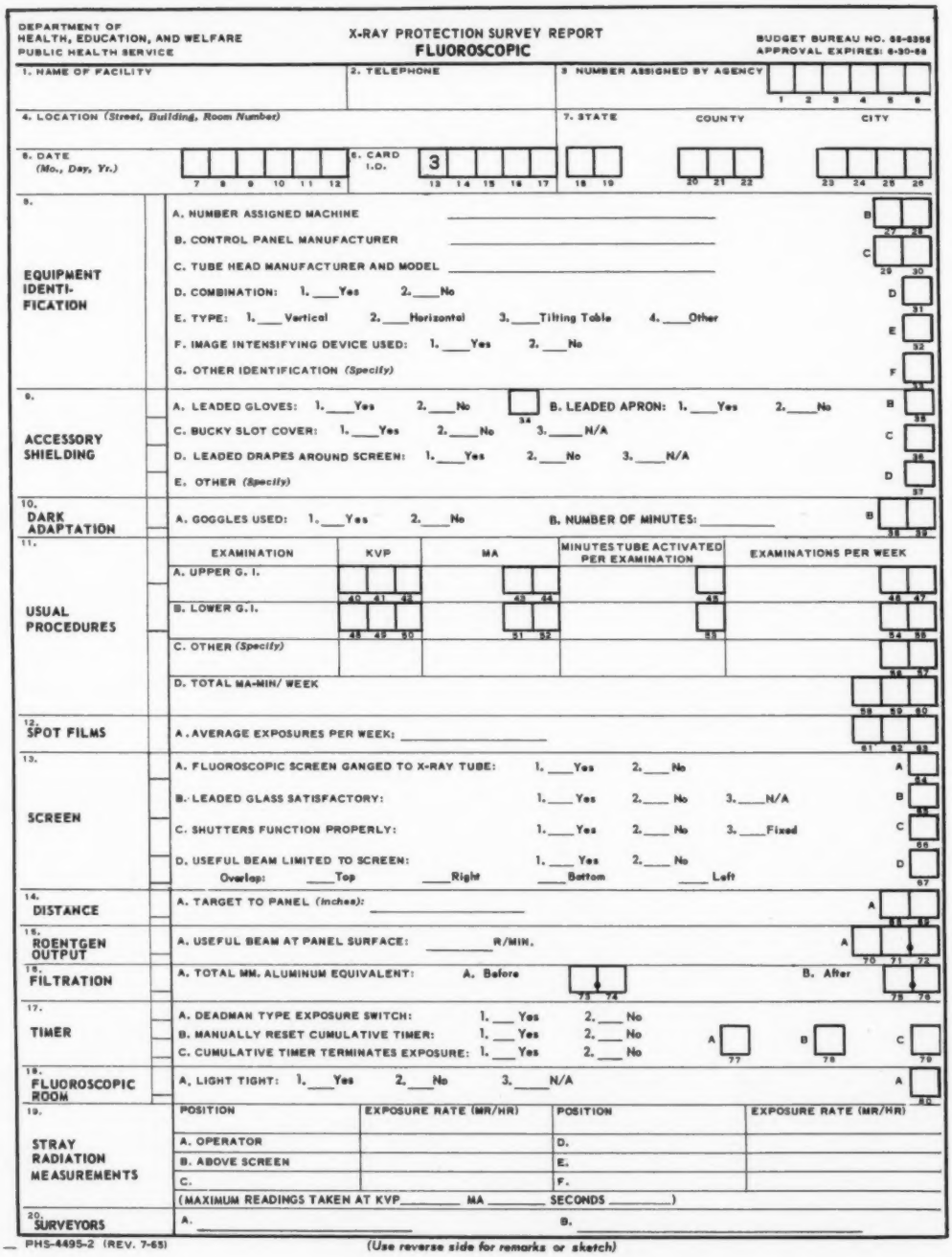
23. SCATTER RADIATION MEASUREMENTS (MAX. READINGS) TAKEN AT K.V.P. _____ M.A. _____

Position	Dose Rate	Position	Dose Rate
A. OPERATOR		C.	
B.		D.	

PHS 4495-2 (REV. 8-63) (USE REVERSE SIDE FOR REMARKS)

Figure 13. "Old" fluoroscopic form—Medical X-ray Protection Survey Reports

XUM



DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE

X-RAY PROTECTION SURVEY REPORT
FLUOROSCOPIC

BUDGET BUREAU NO. 68-R356
APPROVAL EXPIRES: 6-30-66

1. NAME OF FACILITY
2. TELEPHONE
3. NUMBER ASSIGNED BY AGENCY (1 2 3 4 5 6)
4. LOCATION (Street, Building, Room Number)
7. STATE (18 19) COUNTY (20 21 22) CITY (23 24 25 26)
8. DATE (Mo., Day, Yr.) (7 8 9 10 11 12)
6. CARD I.D. 3 (13 14 15 16 17)

9. EQUIPMENT IDENTIFICATION
A. NUMBER ASSIGNED MACHINE _____ B (27 28)
B. CONTROL PANEL MANUFACTURER _____ C (29 30)
C. TUBE HEAD MANUFACTURER AND MODEL _____
D. COMBINATION: 1. ___Yes 2. ___No D (31)
E. TYPE: 1. ___Vertical 2. ___Horizontal 3. ___Tilting Table 4. ___Other E (32)
F. IMAGE INTENSIFYING DEVICE USED: 1. ___Yes 2. ___No F (33)
G. OTHER IDENTIFICATION (Specify)

9. ACCESSORY SHIELDING
A. LEADED GLOVES: 1. ___Yes 2. ___No (34)
B. LEADED APRON: 1. ___Yes 2. ___No B (35)
C. BUCKY SLOT COVER: 1. ___Yes 2. ___No 3. ___N/A C (36)
D. LEADED DRAPES AROUND SCREEN: 1. ___Yes 2. ___No 3. ___N/A D (37)
E. OTHER (Specify)

10. DARK ADAPTATION
A. GOGGLES USED: 1. ___Yes 2. ___No
B. NUMBER OF MINUTES: _____ B (38 39)

11. USUAL PROCEDURES

EXAMINATION	KVP	MA	MINUTES TUBE ACTIVATED PER EXAMINATION	EXAMINATIONS PER WEEK
A. UPPER G. I.	(40 41 42)	(43 44)	(45)	(46 47)
B. LOWER G. I.	(48 49 50)	(51 52)	(53)	(54 55)
C. OTHER (Specify)				(56 57)
D. TOTAL MA-MIN/ WEEK				(58 59 60)

12. SPOT FILMS
A. AVERAGE EXPOSURES PER WEEK: _____ (61 62 63)

13. SCREEN
A. FLUOROSCOPIC SCREEN GANGED TO X-RAY TUBE: 1. ___Yes 2. ___No A (64)
B. LEADED GLASS SATISFACTORY: 1. ___Yes 2. ___No 3. ___N/A B (65)
C. SHUTTERS FUNCTION PROPERLY: 1. ___Yes 2. ___No 3. ___Fixed C (66)
D. USEFUL BEAM LIMITED TO SCREEN: 1. ___Yes 2. ___No D (67)
Overlap: ___Top ___Right ___Bottom ___Left

14. DISTANCE
A. TARGET TO PANEL (Inches): _____ A (68 69)

15. ROENTGEN OUTPUT
A. USEFUL BEAM AT PANEL SURFACE: _____ R/MIN. A (70 71 72)

16. FILTRATION
A. TOTAL MM. ALUMINUM EQUIVALENT: A. Before (73 74) B. After (75 76)

17. TIMER
A. DEADMAN TYPE EXPOSURE SWITCH: 1. ___Yes 2. ___No
B. MANUALLY RESET CUMULATIVE TIMER: 1. ___Yes 2. ___No
C. CUMULATIVE TIMER TERMINATES EXPOSURE: 1. ___Yes 2. ___No
A (77) B (78) C (79)

18. FLUOROSCOPIC ROOM
A. LIGHT TIGHT: 1. ___Yes 2. ___No 3. ___N/A A (80)

19. STRAY RADIATION MEASUREMENTS

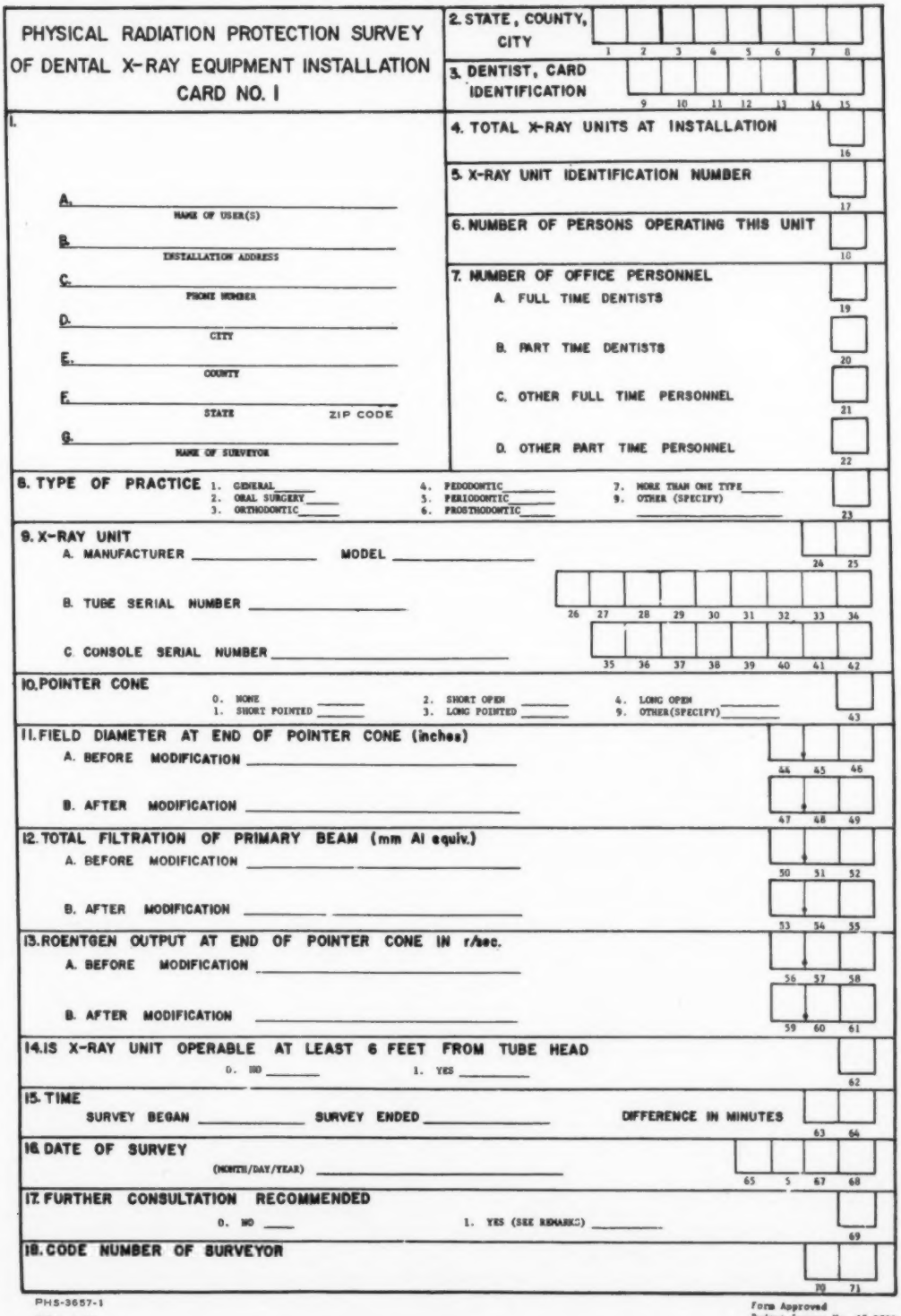
POSITION	EXPOSURE RATE (MR/HR)	POSITION	EXPOSURE RATE (MR/HR)
A. OPERATOR		D.	
B. ABOVE SCREEN		E.	
C.		F.	

(MAXIMUM READINGS TAKEN AT KVP_____ MA _____ SECONDS _____)

20. SURVEYORS
A. _____ B. _____

PHS-4495-2 (REV. 7-65)
(Use reverse side for remarks or sketch)

Figure 16. "New" fluoroscopic form—Medical X-ray Protection Survey Reports



PHYSICAL RADIATION PROTECTION SURVEY OF DENTAL X-RAY EQUIPMENT INSTALLATION CARD NO. 1

2. STATE, COUNTY, CITY [1 2 3 4 5 6 7 8]

3. DENTIST, CARD IDENTIFICATION [9 10 11 12 13 14 15]

1.

A. _____ NAME OF USER(S)

B. _____ INSTALLATION ADDRESS

C. _____ PHONE NUMBER

D. _____ CITY

E. _____ COUNTY

F. _____ STATE ZIP CODE

G. _____ NAME OF SURVEYOR

4. TOTAL X-RAY UNITS AT INSTALLATION [16]

5. X-RAY UNIT IDENTIFICATION NUMBER [17]

6. NUMBER OF PERSONS OPERATING THIS UNIT [18]

7. NUMBER OF OFFICE PERSONNEL

A. FULL TIME DENTISTS [19]

B. PART TIME DENTISTS [20]

C. OTHER FULL TIME PERSONNEL [21]

D. OTHER PART TIME PERSONNEL [22]

8. TYPE OF PRACTICE [23]
1. GENERAL _____ 2. ORAL SURGERY _____ 3. ORTHODONTIC _____ 4. PEDODONTIC _____ 5. PERIODONTIC _____ 6. PROSTHODONTIC _____ 7. MORE THAN ONE TYPE _____ 9. OTHER (SPECIFY) _____

9. X-RAY UNIT
A. MANUFACTURER _____ MODEL _____ [24 25]
B. TUBE SERIAL NUMBER _____ [26 27 28 29 30 31 32 33 34]
C. CONSOLE SERIAL NUMBER _____ [35 36 37 38 39 40 41 42]

10. POINTER CONE [43]
0. NONE _____ 1. SHORT POINTED _____ 2. SHORT OPEN _____ 3. LONG POINTED _____ 4. LONG OPEN _____ 9. OTHER (SPECIFY) _____

11. FIELD DIAMETER AT END OF POINTER CONE (inches)
A. BEFORE MODIFICATION _____ [44 45 46]
B. AFTER MODIFICATION _____ [47 48 49]

12. TOTAL FILTRATION OF PRIMARY BEAM (mm Al equiv.)
A. BEFORE MODIFICATION _____ [50 51 52]
B. AFTER MODIFICATION _____ [53 54 55]

13. ROENTGEN OUTPUT AT END OF POINTER CONE IN r/sec.
A. BEFORE MODIFICATION _____ [56 57 58]
B. AFTER MODIFICATION _____ [59 60 61]

14. IS X-RAY UNIT OPERABLE AT LEAST 6 FEET FROM TUBE HEAD [62]
0. NO _____ 1. YES _____

15. TIME
SURVEY BEGAN _____ SURVEY ENDED _____ DIFFERENCE IN MINUTES [63 64]

16. DATE OF SURVEY
(MONTH/DAY/YEAR) _____ [65 5 67 68]

17. FURTHER CONSULTATION RECOMMENDED [69]
0. NO ____ 1. YES (SEE REMARKS) _____

18. CODE NUMBER OF SURVEYOR [70 71]

PHS-3657-1
REV. 1-67

Form Approved
Budget Bureau No. 50-R733

Figure 17. Dental X-ray Protection Survey Report, side 1

XUM

Kansas State Department of Public Instruction
in cooperation with
Kansas State Department of Health

REGISTRATION OF SCHOOL RADIATION MACHINES FORM

Do not write in this space

School Dist. County City

1 2 3 4 5 6 7 8 9 10 11

Radiation Machines, etc.	Number
X-ray diffraction machines	(12) __
X-ray radiographic machines	(13) __
Hand-held demonstration fluoroscopes . .	(14) __
Shoe-fitting fluoroscopes.	(15) __
Demonstration x-ray tubes.	(16) __
Particle accelerators	(17) __
Electron microscopes	(18) __
Van de Graaff Accelerators	(19) __
Crookes tubes.	(20) __
Geissler tubes	(21) __
Tesla coils	(22) __
Army (or other) surplus:	
Radar	(23) __
Luminous devices	(24) __
High voltage* vacuum tubes	(25) __
Other (specify)_____	(26) __

Do you ever use radioactive isotopes? (27) 1.__Yes 2.__No

Date_____Signature_____

*20,000 volts or more (0.58 cm spark gap between spheres 2.5 cm.in diameter, or 1.75 cm spark gap between needle points)

Form RH-51 (1168)

Figure 1. Registration form for school radiation machines (Inquiry concerning lasers was omitted from this form but information was requested in cover letter)

Survey results

A check of the information on the returned form registration revealed an overestimation of the actual number of devices in Kansas schools, since many teachers are unfamiliar with the identity or names of the devices listed (table 2). Some devices were found to be in storage without anyone's knowledge.

Table 2. Accuracy of replies to questionnaire

Device	Number reported	Number on hand	Number in use
X-ray diffraction	2	0	0
Radiographic	4	2	0
Hand-held fluoroscope	14	9	2
Shoe-fitting fluoroscope	2	1	0
Demonstration x-ray tube	14	14	3
Electron microscope	1	0	0
Crookes tube	21	21	12

The low use rate of the devices is the result of three factors: (1) some teachers do not make use of equipment purchased by their predecessors, (2) some teachers do not wish to operate x-ray producing devices, and (3) the trend in teaching high school science is to present basic scientific principles, rather than applications of technology.

The data on three demonstration x-ray tubes and four Crookes tubes which produced measurable exposure rates are shown in table 3. The table shows that the maximum exposure to any student was calculated to be 750 mR. This exposure was to the hands of 10 high school students over a school year and represented the only situation in which dose to a student could have exceeded the maximum permissible dose of 500 mrem/a as recommended in NCRP report No. 32 (*2*).

The survey indicates that the amount of unnecessary exposure received by a student in school work is significantly smaller than that which, as a patient, he could receive from an unfiltered and uncollimated diagnostic x-ray machine. Therefore, a school survey program based on the following recommendations would not command as high a priority as the location and correction of faulty diagnostic x-ray equipment.

Recommendations

As a result of the information obtained in this survey, the Radiological Health Section will visit the remaining schools which have indicated possession of both a demonstration x-ray tube and a hand-held fluoroscope and recommend discontinuance of hand fluoroscopy. The 35 schools that have indicated possession of demonstration x-ray tubes will be contacted by telephone to verify, locate, and arrange for a survey of those in use. Demonstration x-ray tubes which are capable of being energized will be registered by school location so that an inquiry can be made every 2 years to determine whether the tubes are being activated. In addition, all schools will be advised by letter that:

(1) the Kansas State Department of Health shall be notified of the location of all demonstration x-ray tubes and x-ray machines, and

(2) that Crookes tubes can produce x-rays, but can be operated safely if used for less than one minute per year, a distance greater than 6 feet from the tube is maintained, or a potential of less than 20 kV is used.

Table 3. Exposure data[a]

Device	Use	Output at 6 in from target (R/h)	Use time (min/a)	Student distance (ft)	Student exposure (mR)
Demonstration x-ray tube	Hand fluoroscopy	45	[b] 1	0.5	750
Demonstration x-ray tube	Hand fluoroscopy	4.5	[b] 1	.5	75
Demonstration x-ray tube	Capacitor discharge	45	1	9.0	[c] .5
Crookes tube	Kinetic energy	.60	1	3.0	[d] 24
Crookes tube	Magnetic deflection	.090	1	3.0	2.0
Crookes tube	Magnetic deflection	.012	3	3.0	2.0
Crookes tube	Fluorescence	.015	3	3.0	2.0

[a] Nine Crookes tubes did not register a measurable exposure rate on the CS-40. Of these, one tube was operated at 40 kV, another at 20 kV, and the rest at less than 10 kV.
[b] Per student.
[c] The 0.5 mR exposure is achieved by standing in a position that takes advantage of the shadow produced by the back side of the tube anode.
[d] The 24 mR exposure occurs at a position which is incorrect for observation of the experiment.

REFERENCES

(*1*) PUBLIC HEALTH SERVICE, DIVISION OF REGIONAL OPERATIONS. Radiation Sources in Secondary Schools, ORO 69-5. National Technical Information Service, Springfield, Va. 22151 (1969).
(*2*) NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS. Radiation Protection in Educational Institutions, NCRP Report No. 32. 4000 Brandywine St, N.W., Washington, D.C. 20016 (July 1, 1966).

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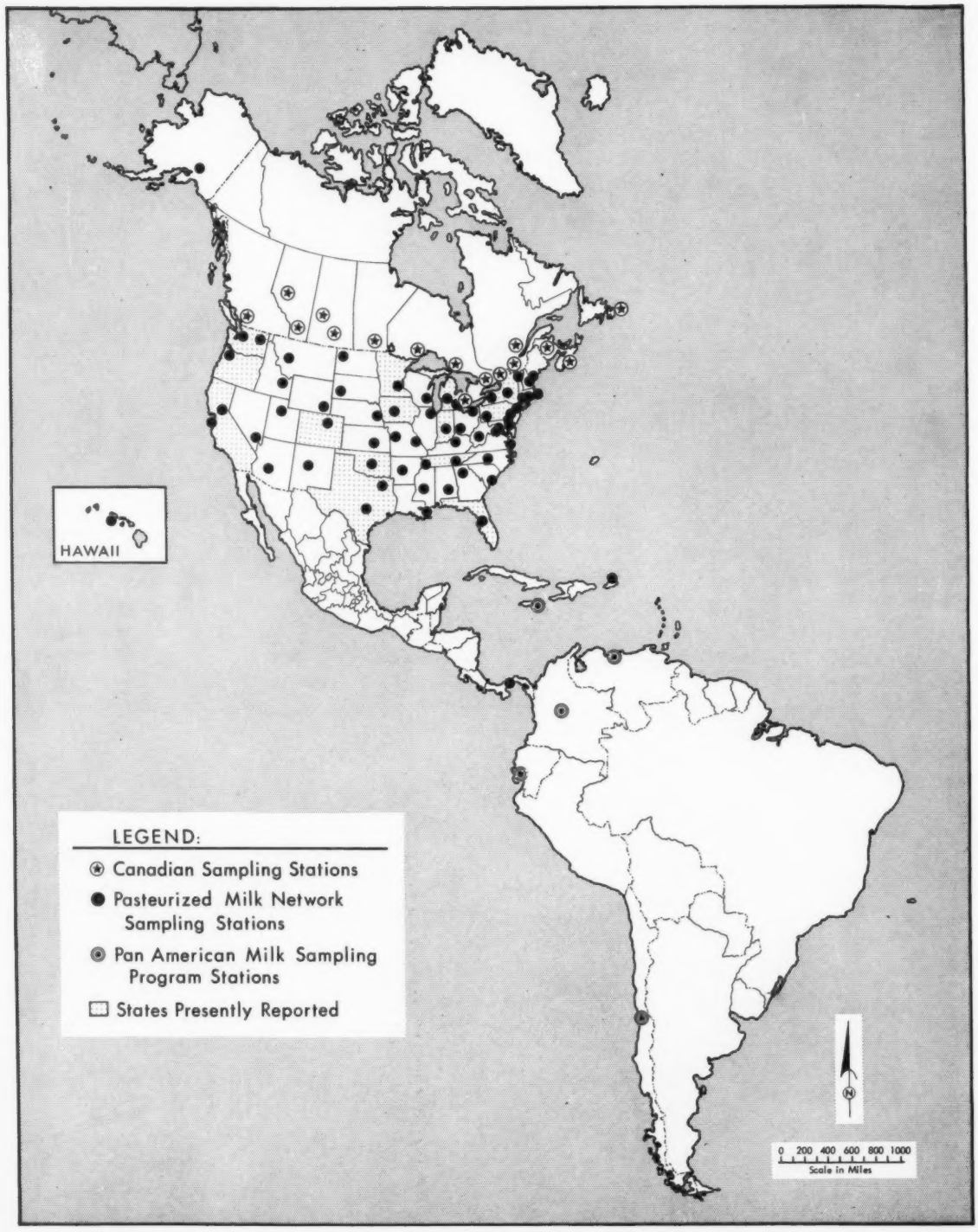

Figure 1. Milk sampling networks in the Western Hemisphere

tium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2-standard deviations (2σ), for these concentrations are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Bureau of Radiological Health conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested public health radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted during May–July 1970, with 28 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140 (*5*). Of the 18 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 12 participated in the experiment.

The accuracy results of this experiment are shown in table 1. In general, considerable improvement is needed, especially in the accuracy measurements. Keeping these possible differences in mind, integration of the data from the various networks can be undertaken.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies.

Table 1. Distribution of mean results, quality control experiment

Isotope and level	Number of laboratories in each category			
	Acceptable ($X \leq \bar{X} \pm 2\sigma$)	Warning level ($\bar{X} \pm 2\sigma < X < \bar{X} \pm 3\sigma$)	Unacceptable ($X > \bar{X} \pm 3\sigma$)	Total
Strontium-89—High (258 pCi/liter)	7 (44%)	1 (6%)	8 (50)%	16
Low (15 pCi/liter)	11 (69%)	3 (19%)	2 (12%)	16
Strontium-90—Intermediate (79.4 pCi/liter)	13 (57%)	4 (17)%	6 (26%)	23
Low (32.0 pCi/liter)	5 (25%)	4 (20%)	11 (55%)	20
Iodine-131—High (507 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
Low (49 pCi/liter)	16 (64%)	3 (12%)	6 (24%)	25
Cesium-137—High (259 pCi/liter)	20 (74%)	3 (11%)	4 (15%)	27
Low (259 pCi/liter)	17 (66%)	5 (19%)	4 (15%)	26
Barium-140—High (302 pCi/liter)[a]	18 (67%)	2 (7%)	7 (26%)	27
Low (33 pCi/liter)	23 (92%)	0	2 (8%)	25

[a] Known concentrations.

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Table 3. Protective Action Guides—FRC recommendations and related information pertaining to environmental levels during an acute contaminating event

Radionuclide	Critical organ	PAG for individuals in general population (rads)	Category (pasture-cow-milk)	
			Guidance for suitable sample, children 1 year of age	
			PAG (rads)	Maximum concentration in milk for single nuclide that would result in PAG (pCi/liter)
Strontium–89	Bone marrow	10 in first year; total dose not to exceed 15[a,b]	3 in first year; total dose not to exceed 5[a,b]	[c] 1,110,000
Strontium–90	Bone marrow			[c] 51,000
Cesium–137	Whole body			[c] 720,000
Iodine–131	Thyroid	30	10	[d] 70,000

[a] The sum of the projected doses of these three radionuclides to the bone marrow should be compared to the numerical value of the respective guide.

[b] Total dose from strontium–89 and cesium–137 is the same as dose in first year; total dose from strontium–90 is 5 times strontium–90 dose in first year for children approximately 1 year of age.

[c] These values represent concentrations that would result in doses to the bone marrow or whole body equal to the PAG, if only the single radionuclide were present.

[d] This concentration would result in the PAG dose based on intake before and after the date of maximum concentration observed in milk from an acute contaminating event. A maximum of 84,000 pCi/liter would result in a PAG dose if that portion of intake prior to the maximum concentration in milk is not considered. Children, 1 year of age, are assumed to be the critical segment of the population.

acute incident, would result in doses equivalent to the appropriate PAG. These concentrations are based on a projection of the maximum concentration from an idealized model for any acute deposition and the pasture-cow-milk-man pathway, as well as an estimate of the intake prior to reaching the maximum concentration. Therefore, these maximum concentrations are intended for use in estimating future intake on the basis of a few early samples rather than in retrospective manner.

Data reporting format

Table 4 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports*. (The relationship between the PMN stations and State stations is shown in figure 2.) The first column under each of the radionuclides reported gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 4, surveillance results are given for strontium-90, iodine-131, and cesium-137 for July 1970 and the 12-month period, August 1969 to July 1970. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have been omitted from table 4 since levels at the great majority of the stations for July 1970 were below the respective practical reporting levels. Table 5 gives monthly averages for those stations at which strontium-89 was detected.

Iodine-131 results are included in table 4, even though they were generally below practical reporting levels. Because of the lower values reflected by the radiation protection guidance provided by the Federal Radiation Council (table 2), levels in milk for this radionuclide are of particular public health interest. In general, the prac-

Table 4. Concentrations of radionuclides in milk for July 1970 and 12-month period, August 1970 through July 1970

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium–90		Iodine–131		Cesium–137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
United States:								
Ala:	Montgomery[c]	P	5	6	0(2)	0	0(2)	9
Alaska:	Palmer[c]	P	7	5	0	0	15	5
Ariz:	Phoenix[c]	P	NA	1	0	0	0	0
Ark:	Little Rock[c]	P	13	13	0(2)	0	19(2)	18
Calif:	Sacramento[c]	P	NA	1	0	0	0	0
	San Francisco[c]	P	0	2	0(2)	0	0(2)	0
	Del Norte	P	19	19	0	0	15	20
	Fresno	P	2	2	0	0	0	3
	Humboldt	P	4	5	0	0	0	6
	Los Angeles	P	2	2	0	0	0	3
	Mendocino	P	4	3	0	0	0	3
	Sacramento	P	4	3	0	0	0	3
	San Diego	P	2	2	0	0	0	1
	Santa Clara	P	2	2	0	0	0	2
	Shasta	P	4	3	0	0	0	3
	Sonoma	P	3	3	0	0	0	3
Colo:	Denver[c]	P	5	5	0(2)	0	0(2)	1
	West	R	[d]		[e]0(3)	0	[e] 0(3)	4
	Northeast	R	[d]		[e]0(2)	0	[e] 0(2)	0
	East	R	[d]		[e]0	0	[e] 0	0
	Southeast	R	[d]		[e]0	0	[e] 0	0
	South central	R	[d]		NS	NS	NS	NS
	Southwest	R	[d]		[e]0	0	[e] 0	6
	Northwest	R	[d]		NS	0	NS	0
Conn:	Hartford[c]	P	8	8	0(2)	0	22(2)	11
	Central	P	7	7	0(3)	0	23(3)	13
Del:	Wilmington[c]	P	13	9	0	0	23	7
D.C:	Washington[c]	P	8	7	0(2)	0	7(2)	6
Fla:	Tampa[c]	P	7	6	0(2)	0	65(2)	53
	West	R	9	11	0	0	27	23
	North	R	13	11	0	0	27	24
	Northeast	R	6	7	0	0	70	45
	Central	R	5	7	0	0	123	54
	Tampa Bay area	R	5	7	0	0	70	53
	Southeast	R	7	7	0	0	139	76
Ga:	Atlanta[c]	P	8	10	0(4)	0	18(4)	18
Hawaii:	Honolulu[c]	P	4	2	0	0	0	0
Idaho:	Idaho Falls[c]	P	7	5	0	0	20	4
Ill:	Chicago[c]	P	8	8	0	0	17	9
Ind:	Indianapolis[c]	P	7	8	0	0	11	5
	Northeast	P	14	9	0	1	20	16
	Southeast	P	11	10	0	0	10	13
	Central	P	12	9	0	0	0	10
	Southwest	P	16	11	0	0	15	14
	Northwest	P	15	10	0	0	20	17
Iowa:	Des Moines[c]	P	6	6	0(2)	0	10(2)	2
	Iowa City	P	NS	8	NS	0	NS	10
	Des Moines	P	11	7	0(4)	0	13	6
	Spencer	P	5	6	0	0	13	6
	Fredericksburg	P	NS	NS	NS	NS	NS	NS
Kans:	Wichita[c]	P	6	8	0	0	11	1
	Coffeyville	P	NA	8	0	0	0	0
	Dodge City	P	NA	7	0	1	0	1
	Falls City, Nebr	R	NA	9	0	0	0	0
	Hays	R	NA	8	0	0	0	0
	Kansas City	P	NA	9	0	0	0	0
	Topeka	P	NA	9	0	0	11	2
	Wichita	P	NA	7	0	0	0	0
Ky:	Louisville[c]	P	9	8	0(2)	0	3(2)	4
La:	New Orleans[c]	P	17	15	0(2)	0	20(2)	18
Maine:	Portland[c]	P	12	11	0	0	32	23
Md:	Baltimore[c]	P	8	8	0	0	19	8
Mass:	Boston[c]	P	11	10	0	0	38	21
Mich:	Detroit[c]	P	10	8	0	0	15	8
	Grand Rapids[c]	P	10	9	0	0	12	10
	Bay City	P	7	7	[e]0	0	16	9
	Charlevoix	P	11(2)	12	[e]0(3)	0	24(3)	18
	Detroit	P	10	8	[e]0	0	16	6
	Grand Rapids	P	10	8	[e]0	0	13	11
	Lansing	P	10(2)	9	[e]0(2)	0	15(2)	15
	Marquette	P	14(2)	13	[e]0(2)	1	35(2)	24
	Monroe	P	7	6	[e]0(2)	0	24(2)	4
	South Haven	P	8(2)	8	[e]0(4)	0	14(4)	7
Minn:	Minneapolis[c]	P	14	10	0	0	22	8
	Bemidji	P	6	13	0	0	18	23
	Mankato	P	3	6	0	0	15	11
	Rochester	P	4	7	0	0	11	17
	Duluth	P	17	16	0	0	55	26
	Worthington	P	4	5	0	0	14	7
	Minneapolis	P	7	10	0	0	21	14
	Fergus Falls	P	4	7	0	0	18	11
	Little Falls	P	18	9	0	0	120	22

See footnotes at end of table.

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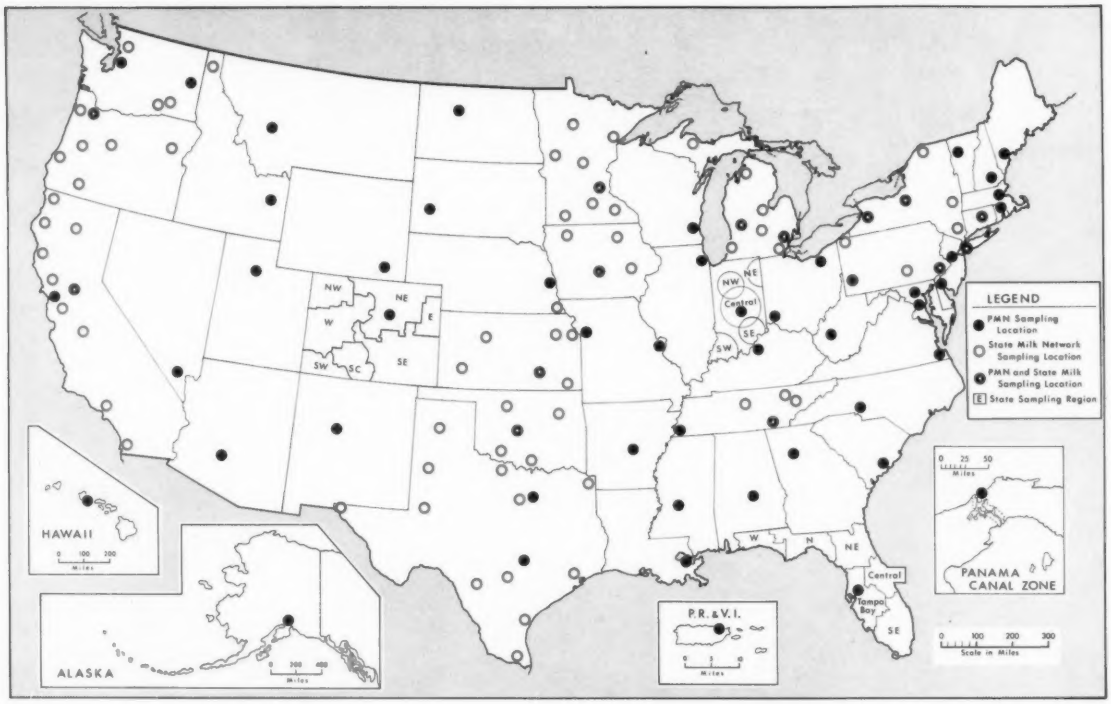

Figure 2. State and PMN milk sampling locations in the United States

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Environmental Health Services
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Environmental Radiation Surveillance Program
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Bureau of Environmental Health
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Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Office of Air Quality Control
Division of Technical Services
Washington State Department of Health

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Table 1. Estimated daily intake of radionuclides in California diet[a] April–June 1969

City	Consumption (kg/capita • day)[b]	Intake[c] (pCi/capita • day)				Intake (g/capita • day)		
		^{89}Sr	^{90}Sr	^{226}Ra	^{137}Cs	K[d]	Na	Ca
Bakersfield	2.1	0	6	1.6	9	3.0	4.1	1.1
Berkeley	NS							
Bishop	1.8	2	6	1.0	10	2.6	3.1	.8
Brawley	NS							
Crescent City	2.5	15	17	1.9	22	4.0	4.5	1.0
Eureka	2.3	3	8	1.5	16	2.5	4.3	.6
Fresno	2.1	0	8	1.2	23	3.2	3.1	1.6
Los Angeles	1.7	1	4	.9	5	2.1	3.1	.6
Needles	2.3	1	1	1.0	10	2.7	3.1	1.0
Quincy	2.3	6	9	1.4	16	3.3	4.0	1.1
Redding	2.3	3	7	1.4	29	3.2	3.6	1.0
Sacramento	2.7	1	8	1.0	11	2.9	5.3	1.3
Salinas	2.4	0	6	.9	12	3.1	5.6	1.0
San Bernardino	1.9	3	7	.9	7	3.1	4.2	1.0
San Diego	2.0	0	6	1.0	12	2.9	3.4	.8
San Luis Obispo	2.1	2	6	1.5	16	3.1	4.0	1.3
Santa Barbara	1.9	0	5	.5	8	2.7	2.4	.9
Santa Rosa	1.8	3	9	.9	9	2.2	2.7	1.1
Susanville	1.8	4	5	1.3	8	2.2	2.9	.9
Ukiah	2.1	3	5	1.5	6	3.1	3.7	1.2

[a] Based on analyses of Hospital Standard Diets located in listed cities.
[b] Kilograms of food per person per day in this diet.
[c] Manganese-54, zirconium-95, and cerium-141–144 were less than their reporting levels during this period (managnese-54, 7 pCi/capita•day; zirconium-95, 7 pCi/capita•day; and cerium-141–144, 10 pCi/capita•day).
[d] Natural potassium contains 0.0119 percent of radioactive potassium-40.

Table 2. Estimated daily intake of radionuclides in California diet[a] July–September 1969

City	Consumption (kg/capita • day)[b]	Intake[c] (pCi/capita • day)							Intake (g/capita • day)		
		^{89}Sr	^{90}Sr	^{226}Ra	^{137}Ca	^{140}Ba-La	^{95}Zr-Nb	^{54}Mn	K[d]	Na	Ca
Bakersfield	1.8	3	5	1.4	8	0	0	1	2.8	3.3	1.1
Berkeley	NS										
Bishop	1.6	0	5	1.1	7	0	0	4	2.5	1.8	.7
Brawley	2.1	1	6	.4	14	5	0	1	3.3	3.2	0.8
Crescent City	2.6	9	16	.9	16	0	0	0	3.4	4.2	1.2
Eureka	2.2	1	8	1.4	10	0	0	0	2.9	3.8	.9
Fresno	2.2	2	5	.8	11	0	0	1	3.2	3.0	1.1
Los Angeles	2.1	3	10	2.3	10	0	0	5	3.2	3.4	1.2
Needles	2.3	3	8	1.2	7	0	0	5	2.7	2.8	1.5
Quincy	2.3	3	6	1.8	3	0	0	0	3.2	2.8	1.0
Redding	3.0	8	10	1.7	7	0	0	3	3.8	3.7	1.1
Sacramento	2.6	2	8	2.2	0	0	4	12	3.4	5.0	1.5
Salinas	2.4	9	4	3.2	0	0	8	9	3.4	6.0	0.8
San Bernardino	2.2	1	3	.9	2	0	3	10	3.5	4.4	.5
San Diego	1.9	7	6	2.5	7	0	0	4	3.2	4.2	1.9
San Luis Obispo	1.9	1	7	2.1	0	0	1	9	2.9	4.2	1.5
Santa Barbara	1.7	2	5	.4	10	0	0	2	2.5	1.1	1.1
Santa Rosa	1.6	3	5	.2	7	0	0	1	2.0	2.9	1.3
Susanville	1.7	4	1	.9	5	0	0	3	2.1	2.1	.6
Ukiah	1.8	0	5	.9	7	0	1	2	2.8	2.9	1.2

[a] Based on analyses of Hospital Standard Diets located in listed cities.
[b] Kilograms of food per person per day in this diet.
[c] Cerium-141–144 was less than its respective reporting level of 10 pCi/capita•day during this period.
[d] Natural potassium contains 0.0119 percent of radioactive potassium-40.
NS, no sample.

Table 3. Estimated daily intake of radionuclides in California diet[a] October–December 1969

City	Consumption (kg/capita·day)[b]	Intake[c] (pCi/capita·day)						Intake (g/capita·day)		
		^{89}Sr	^{90}Sr	^{226}Ra	^{137}Cs	^{95}Zr-Nb	^{54}Mn	K[d]	Na	Ca
Bakersfield	2.1	0	15	1.5	0	4	8	3.2	4.3	1.3
Berkeley	NS									
Bishop	1.7	6	5	1.5	0	0	11	3.2	2.9	1.2
Brawley	1.4	0	4	1.3	2	4	6	1.8	2.7	.7
Crescent City	2.2	9	5	1.3	6	4	4	3.0	3.9	.7
Eureka	2.2	1	7	1	5	0	9	3.0	4.0	.9
Fresno	1.9	1	7	1	5	0	9	3.3	2.7	1.2
Los Angeles	2.0	0	4	1	9	3	13	2.9	3.2	.9
Needles	2.3	2	6	1	7	0	10	2.8	3.0	1.1
Quincy	2.3	4	5	1	11	0	12	3.0	2.8	.9
Redding	2.6	0	20	2	2	2	13	3.2	3.4	1.7
Sacramento	2.7	0	7	1	3	4	4	3.2	4.5	1.2
Salinas	2.4	1	7	1	10	0	7	3.4	6.1	.9
San Bernardino	2.2	4	4	1	0	0	5	3.5	4.1	1.0
San Diego	2.0	0	7	1	16	5	13	3.0	2.8	.8
San Luis Obispo	2.6	1	10	2	12	0	17	3.6	4.1	1.5
Santa Barbara	NS									
Santa Rosa	2.0	0	6	2	3	4	7	2.5	3.2	0.9
Susanville	1.8	2	3	0	6	0	7	2.1	2.5	1.1
Ukiah	1.9	1	8	1	0	2	8	2.8	3.6	1.5

[a] Based on analyses of Hospital Standard Diets located in listed cities.
[b] Kilograms of food per person per day in this diet.
[c] Barium-lanthanum-140 and cerium-141–144 were less than their respective reporting levels of 5 pCi/capita·day and 10 pCi/capita·day during this period.
[d] Natural potassium contains 0.0119 percent of radioactive potassium-40.
NS, no sample.

Table 4. Estimated daily intake of radionuclides in California diet[a] January–March 1970

City	Consumption (kg/capita·day)[b]	Intake[c] (pCi/capita·day)						Intake (g/capita·day)		
		^{89}Sr	^{90}Sr	^{226}Ra	^{137}Cs	^{95}Zr-Nb	^{54}Mn	K[d]	Na	Ca
Bakersfield	2.1	1	4	1.5	27	0	0	3.6	5.3	0.8
Berkeley	NS									
Bishop	1.7	3	4	.7	9	0	7	2.6	2.6	1.1
Brawley	2.1	3	6	1.2	1	2	6	2.8	3.8	.8
Crescent City	2.8	8	14	.7	30	0	0	3.8	5.4	1.4
Eureka	2.3	5	6	1.1	10	0	4	2.9	4.0	.6
Fresno	2.1	1	6	.9	7	0	5	3.2	2.2	1.2
Los Angeles	2.2	3	5	.6	9	1	12	3.1	3.9	.8
Needles	2.3	6	5	.7	13	0	1	2.5	2.6	.8
Quincy	1.9	2	4	.6	7	0	3	2.8	2.8	.6
Redding	2.7	3	6	1.5	5	3	12	4.0	3.3	1.3
Sacramento	2.6	0	11	1.6	8	0	12	3.6	4.6	1.1
Salinas	2.4	2	6	.9	7	0	4	3.7	6.5	1.0
San Bernardino	2.1	13	6	.8	8	0	8	4.4	3.4	1.1
San Diego	2.2	5	6	1.6	9	0	9	3.3	3.3	.8
San Luis Obispo	2.3	1	5	.5	5	0	6	3.2	4.2	1.0
Santa Barbara	2.3	4	6	1.1	13	2	9	3.0	3.1	1.7
Santa Rosa	2.2	3	5	.3	5	0	10	3.0	4.2	1.2
Susanville	1.7	2	7	1.1	7	2	7	2.5	3.0	1.1
Ukiah	1.7	2	6	1.9	12	0	9	1.8	2.3	1.1

[a] Based on analyses of Hospital Standard Diets located in listed cities.
[b] Kilograms of food per person per day in this diet.
[c] Barium-lanthanum-140 and cerium-141–144 were less than their respective reporting levels of 5 pCi/capita·day and 10 pCi/capita·day during this period.
[d] Natural potassium contains 0.0119 percent of radioactive potassium-40.
NS, no sample.

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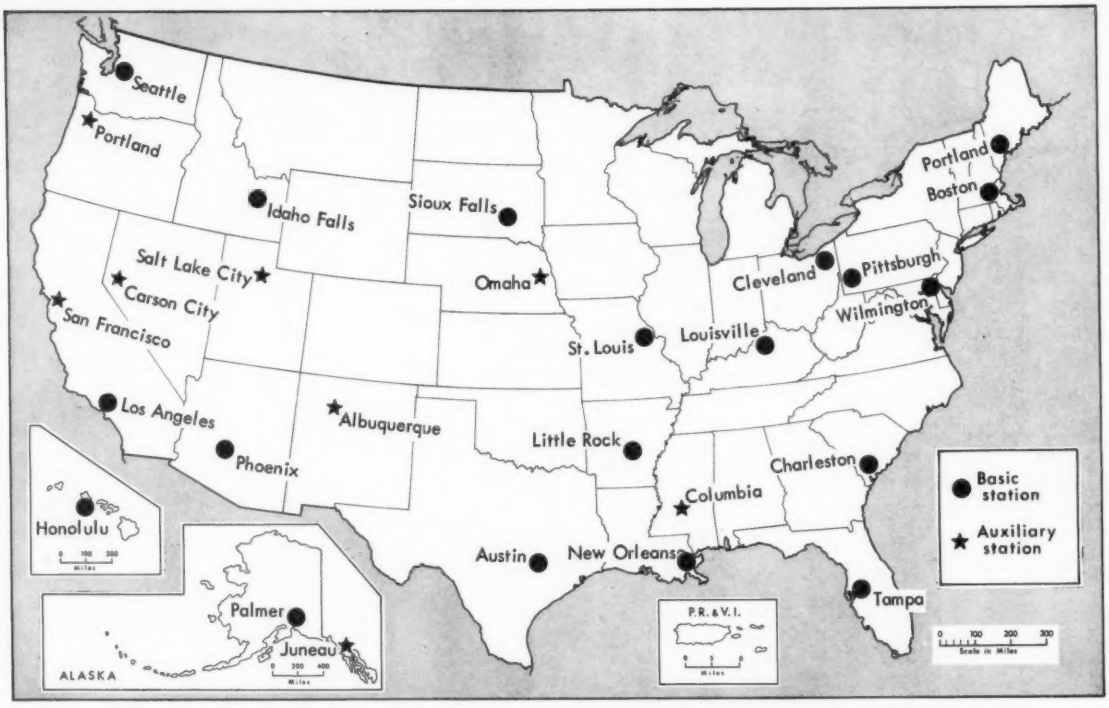

Figure 1. Institutional diet sampling locations as of December 1969

until the end of the collection period and is then packed in dry ice and shipped by air express to either the Southwestern Radiological Health Laboratory, Las Vegas, Nev., the Southeastern Radiological Health Laboratory, Montgomery, Ala., or the Northeastern Radiological Health Laboratory, Winchester, Mass. A detailed description of sampling and analytical procedures was presented earlier (*3*).

Results

Table 1 presents the analytical results for institutional diet samples collected from January through March 1970 for children 9 to 12 years of age. The stable elements, calcium and potassium, are reported in g/kg of diet. The radionuclide concentration of these samples, reported in pCi/kg of diet, are corrected for radioactive decay to the midpoint of the sample collection period, where applicable. Dietary intakes in g/day or pCi/day were obtained by multiplying the food consumption rate in kg/day by the appropriate concentration values. The average food consumption rate during this period was 1.94 kg/day compared to the network average of 1.87 kg/day observed from 1961 through 1969.

Strontium-90 dietary intake during this period averaged 11 pCi/day. This result falls within Range I as defined by the Federal Radiation Council (*4*). Cesium-137 intake averaged 13 pCi/day during this period. In general, strontium-89, iodine-131, and barium-140 concentrations were below detectable levels.

All concentrations that are less than or equal to the appropriate minimum detectable level have been reported as zero. The minimum detectable concentration is defined as the measured concentration equal to the 2-standard deviation analytical error. Accordingly, the minimum detectable imits are as follows:

Table 1. Concentration and intake of stable elements and radionuclides in institutional total diets of children (9–12 years of age), January–March 1970

Location of Institution	Month (1970)	Total weight (kg/day)	Calcium		Potassium		Strontium-89		Strontium-90		Cesium-137	
			(g/kg)	(g/day)	(g/kg)	(g/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)
Alaska: Palmer	Jan	NS	NS		NS		NS		NS		NS	
	Feb	NS	NS		NS		NS		NS		NS	
	Mar	1.52	0.5	0.7	1.0	1.5	0	0	5	8	0	0
Ariz: Phoenix	Jan	1.79	[b].8	[b]1.3	1.2	2.2	[b]0	[b]0	[b]6	[b]10	0	0
	Feb	1.49			1.4	2.1					0	0
	Mar	NS										
Ark: Little Rock	Jan	1.45	[b].7	[b]1.0	1.5	2.2	[b]NA	[b]NA	[b]10	[b]13	0	0
	Feb[a]	1.41			1.4	2.0					12	17
	Mar[a]	1.28			1.5	1.9					14	18
Calif: Los Angeles	Jan	NS	NS		NS		NS		NS		NS	
	Feb	NS	NS		NS		NS		NS		NS	
	Mar[a]	1.21	.3	.4	1.0	1.2	0	0	0	0	0	0
Del: Wilmington	Jan	2.15	[b].7	[b]1.5	1.5	3.2	[b]NA	[b]NA	[b]4	[b]9	0	0
	Feb	2.22			1.5	3.4					0	0
	Mar	2.02			1.6	3.2					0	0
Fla: Tampa	Jan[a]	1.58	[b].6	[b].9	1.2	1.8	[b]NA	[b]NA	[b]8	[b]12	14	22
	Feb	1.34			1.6	2.1					21	28
	Mar[a]	1.56			1.6	2.5					13	20
Hawaii: Honolulu	Jan	2.33	[b].4	[b]1.0	1.4	3.3	[b]0	[b]0	[b]0	[b]0	17	40
	Feb	2.37			1.4	3.3					11	26
	Mar	2.43			1.3	3.2					12	29
Idaho: Idaho Falls	Jan[a]	1.94	[b]1.0	[b]1.9	1.3	2.5	[b]0	[b]0	[b]7	[b]14	0	0
	Feb[a]	1.99			1.4	2.9					14	29
	Mar[a]	1.89			1.7	3.2					22	42
Ky: Louisville	Jan	2.52	[b].6	[b]1.6	1.6	4.1	[b]NA	[b]NA	[b]7	[b]17	0	0
	Feb	2.35			1.6	3.8					11	26
	Mar	2.52			1.7	4.2					12	30
La: New Orleans	Jan[a]	1.98	[b].6	[b]1.1	1.4	2.8	[b]0	[b]0	[b]7	[b]13	11	22
	Feb	1.87			1.4	2.6					0	0
	Mar[a]	1.74			1.6	2.8					0	0
Maine: Portland	Jan	1.53	[b].8	[b]1.3	1.7	2.6	[b]NA	[b]NA	[b]11	[b]18	0	0
	Feb	1.73			1.7	2.9					12	21
	Mar	1.79			1.7	3.0					19	34
Mass: Boston	Jan	2.20	[b].6	[b]1.4	1.5	3.3	[b]NA	[b]NA	[b]5	[b]11	0	0
	Feb	2.20			1.4	3.1					15	34
	Mar	2.21			1.5	3.3					12	26
Mo: St. Louis	Jan[a]	2.29	[b]1.0	[b]2.1	1.6	3.7	[b]NA	[b]NA	[b]5	[b]11	0	0
	Feb[a]	1.88			1.7	3.2					0	0
	Mar[a]	2.23			1.8	4.0					0	0
Ohio: Cleveland	Jan	1.57	[b].6	[b]1.0	1.5	2.4	[b]NA	[b]NA	[b]11	[b]16	0	0
	Feb	1.64			1.6	2.6					19	31
	Mar	1.24			1.7	2.1					0	0
Pa: Pittsburgh	Jan	2.24	[b].6	[b]1.2	1.4	3.1	[b]NA	[b]NA	[b]6	[b]13	14	31
	Feb	2.00			1.4	2.8					11	22
	Mar	2.27			1.3	2.9					0	0
S.C: Charleston	Jan	1.58	[b].8	[b]1.4	1.5	2.3	[b]0	[b]0	[b]8	[b]14	19	30
	Feb	1.74			1.6	2.7					0	0
	Mar	1.76			1.4	2.5					0	0
S. Dak: Sioux Falls	Jan[a]	1.53	[b].6	[b]1.0	1.6	2.4	[b]NA	[b]NA	[b]5	[b]8	0	0
	Feb[a]	1.68			1.4	2.4					0	0
	Mar[a]	1.55			1.7	2.6					0	0
Tex: Austin	Jan[a]	1.70	[b].8	[b]1.4	1.7	2.8	[b]NA	[b]NA	[b]6	[b]10	0	0
	Feb[a]	2.27			1.5	3.4					0	0
	Mar[a]	1.51			1.4	2.1					0	0
Wash: Seattle	Jan	NS	NS		NS		NS		NS		NS	
	Feb	NS	NS		NS		NS		NS		NS	
	Mar[a]	2.23	.5	1.1	1.5	3.3	0	0	3	6	0	0
Institutional average	Jan	1.94	0.7	1.2	1.5	2.9	0	0	6	11	5	10
	Feb	1.90			1.5	2.9					9	17
	Mar	1.97			1.5	2.9					6	13

[a] Since food samples were collected from two or more children who were not between the ages of 9 to 12, the sample weights and gamma analyses for this month were not used in the institutional average. All chemistry data was included in the institutional average since this analysis was a composite of three or less individual samples.

[b] Composite analysis of three or less individual monthly samples.

Note: Since iodine-131 and barium-140 were not detected at most stations during this period, no provision was made for these radionuclides in the table. The one exception is as follows: February: 11 pCi/kg of iodine-131 was reported in Cleveland, Ohio.

NA, no analysis.

NS, no sample.

Strontium-89	5 pCi/kg
Strontium-90	2 pCi/kg
Iodine-131	10 pCi/kg
Cesium-137	10 pCi/kg
Barium-140	10 pCi/kg

Data from eight auxiliary stations are included in a separate table for general information (table 2). These stations do not meet the criterion that the majority of the samples are collected from children who range in age from 9–12 years. In

XUM

Table 2. Concentration and intake of stable elements and radionuclides in institutional total diets of individuals (auxiliary stations), January–March 1970

Location of Institution	Month (1970)	Total weight (kg/day)	Calcium		Potassium		Strontium-89[a]		Strontium-90[a]		Cesium-137	
			(g/kg)	(g/day)	(g/kg)	(g/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)
Alaska: Juneau	Jan	NS	NS		NS		NS		NS		NS	
	Feb	NS	NS		NS		NS		NS		NS	
	Mar	1.21	0.4	0.5	1.8	2.2	0	0	0	0	0	0
Calif: San Francisco	Jan	NS	NS		NS		NS		NS		NS	
	Feb	NS	NS		NS		NS		NS		NS	
	Mar	1.78	.6	1.0	1.6	2.8	0	0	5	9	0	0
Miss: Columbia	Jan	1.98	[a]1.0	[a]2.0	1.6	3.2	[a]NA	[a]NA	[a]8	[a]16	13	26
	Feb	2.14			1.5	3.2					0	0
	Mar	1.89			1.5	2.8					0	0
Nebr: Omaha	Jan	2.16	[a].9	[a]1.9	1.6	3.5	[a]NA	[a]NA	[a]5	[a]11	0	0
	Feb	2.19			1.6	3.5					0	0
	Mar	2.15			1.7	3.7					0	0
Nev: Carson City	Jan	NS	NS		NS		NS		NS		NS	
	Feb	NS	NS		NS		NS		NS		NS	
	Mar	2.07	.7	1.5	1.6	3.2	0	0	14	29	0	0
N. Mex: Albuquerque	Jan	2.35	[a]1.0	[a]2.4	1.6	3.8	[a]NA	[a]NA	[a]3	[a]6	14	33
	Feb	2.48			1.5	3.8					0	0
	Mar	2.31			1.7	3.8					0	0
Oreg: Portland	Jan	NS	NS		NS		NS		NS		NS	
	Feb	NS	NS		NS		NS		NS		NS	
	Mar	2.01	.5	1.1	1.8	3.6	0	0	2	5	0	0
Utah: Salt Lake City	Jan	2.84			1.1	3.1					0	0
	Feb	2.10			1.3	2.7					0	0
	Mar	2.69	.5	1.2	1.2	3.1	0	0	4	10	0	0
Institutional average	Jan	2.33	.7	1.4	1.5	3.4	0	0	5	11	7	15
	Feb	2.23			1.5	3.3					0	0
	Mar	2.01			1.6	3.2					0	0

[a] Composite analysis of three or less individual samples.
NA, no analysis.
NS, no sample.
Note: Since iodine-131 and barium-140 were not detected at these stations during this period, no provision was made for these nuclides in this table.

order to supplement the existing environmental monitoring networks of the Bureau of Radiological Health, these eight institutions are being sampled in the same manner as the basic stations.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
April–June 1969	January 1970
July–September 1969	June 1970
October–December 1969 and Annual Summary 1969	August 1970

REFERENCES

(1) ANDERSON, E. C., D. J. NELSON, Jr. Surveillance for radiological contamination in foods. Amer J Public Health 52:1391–1400 (September 1962).

(2) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Radionuclides in institutional total diet samples, January–March 1965. Radiol Health Data 6:548–554 (October 1965).

(3) PUBLIC HEALTH SERVICE, NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Radionuclides in institutional total diet samples, January–March 1968. Radiol Health Data 9:557–560 (October 1968).

(4) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

SECTION II. WATER

The Public Health Service, the Federal Water Quality Administration, and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	July–December 1968	August 1970
Minnesota	January–June 1969	January 1970
New York	January–June 1969	June 1970
Kansas	January–December 1969	September 1970
North Carolina	January–December 1967	May 1969
Radiostrontium in Tap Water, *HASL*	January–December 1969	July 1970
Washington	July 1967–June 1968	June 1969

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Supreintendent of Documents. U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

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Tritium in Surface Water Network January-June 1970

Bureau of Radiological Health
U.S. Public Health Service

The tritium sampling network was established by the Public Health Service in May 1964 to measure and monitor tritium concentrations in major river systems in the United States and to provide surveillance at selected surface water stations downstream from nuclear facilities. The network consists of 8 stations selected from the 131 existing water pollution sampling stations operated by the Federal Water Quality Administration (FWQA); six of the stations are located downstream from nuclear facilities and two stations serve to establish baseline levels (figure 1).

Monthly composites of weekly samples are collected through the FWQA and sent to the Southeastern Radiological Health Laboratory for analysis. The analyses are carried out using liquid scintillation counting techniques described by Moghissi et al. (*1-2*). The minimum level of detectability is 0.2 nCi/liter.

Data for the samples collected during January–June 1970 are shown in table 1. Station averages for this period and the corresponding period of 1969 are also presented in the table. The highest concentration observed during the first 6 months of 1970 was 6.4 nCi/liter (Clinch River-Kingston, Tenn.). The highest 6-month average, 2.5 nCi/liter, was also observed at the Clinch River station. Assuming that the specific activity of tritium in the body is essentially the same as that in the surface water, this average concentration corresponds to an estimated whole-body dose[1] of 0.4 mrem/a; or in terms of Federal Radiation Council guidance, less than 1 percent of the Radiation Protection Guide (170 mrem/a) for an average dose to a suitable sample of the exposed

[1] Development of the calculations to obtain this dose may be found in reference (*3*).

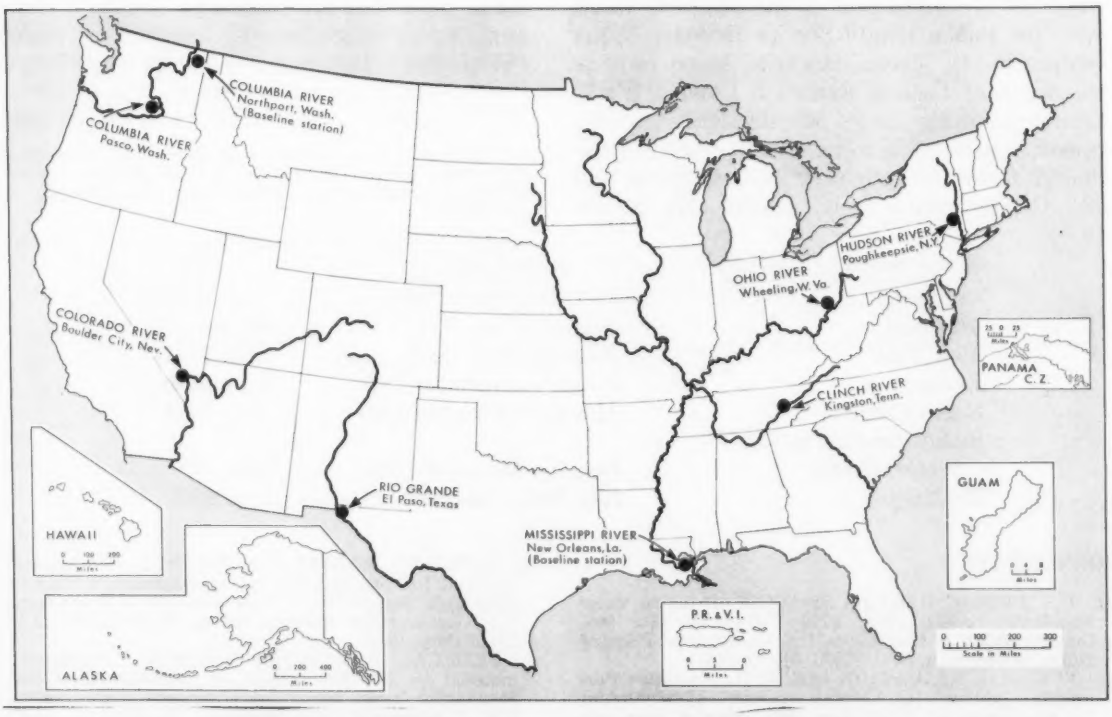

Figure 1. Sampling stations for tritium in surface waters

Table 1. Tritium concentration in surface waters January–June 1970

Collection site	Concentration (nCi/liter)							
	January	February	March	April	May	June	January–June average for:	
							1970	1969
Clinch River: Kingston, Tenn	2.9±0.3	1.8±0.2	[a]0	NS	6.4±0.3	1.2±0.2	2.5	14.4
Colorado River: Boulder City, Nev[b]	1.2± .2	NS	1.0±0.2	0.9±0.2	.7± .2	4.1± .3	1.6	1.4
Columbia River: Northport, Wash[b]	.5± .2	.6± .2	.8± .2	NS	NS	NS	.6	1.0
Columbia River: Pasco, Wash	[a]0	.5± .2	.5± .2	NS	NS	NS	.3	1.0
Hudson River: Poughkeepsie, N.Y.	[a]0	[a]0	[a]0	NS	NS	NS	0	.4
Mississippi River: New Orleans, La	[a]0	[a]0	NS	NS	NS	NS	0	.2
Ohio River: Wheeling, W. Va	[a]0	[a]0	[a]0	[a]0	[a]0	.5± .2	.1	.3
Rio Grande: El Paso, Tex	[a]0	[a]0	.3± .2	.7± .2	[a]0	.3± .2	.2	.1

[a] All values less than or equal to the practical reporting level (0.2 nCi/liter) are reported as 0. The error reported is the 2-sigma error at the 95-percent confidence level.
[b] Baseline station.
NS, no sample.

population (*4*). In general, the 6-month station averages were at the same level for this period as for the same period in 1969, except in the Clinch River where the 6-month average decreased from 14.4 nCi/liter in 1969 to 2.5 nCi/liter in 1970. This network will be expanded in July 1970 to include more sampling locations near operating and planned nuclear facilities.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1969	November 1969
July–December 1969	July 1970

REFERENCES

(*1*) MOGHISSI, A. A., H. L. KELLEY, J. E. REGNIER, and M. W. CARTER. Low-level counting by liquid scintillation-I. tritium measurement in homogeneous systems. Inter J Appl Rad Isotopes 20:145 (1969).

(*2*) LIEBERMAN, R. and A. A. MOGHISSI. Low-level counting by liquid scintillation—II. applications of emissions in tritium counting. Inter J Appl Rad Isotopes 21:319 (1970).

(*3*) MOGHISSI, A. A. and C. R. PORTER. Tritium in surface waters in the United States, 1966. Radiol Health Data Rep 9:337–339 (July 1968).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. (May 13, 1960).

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SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports*:

Network	Period	Issue
Fallout in the United States and Other Areas, *HASL*	January–June 1968	October 1969
Plutonium in Airborne Particulates and Precipitation, *PHS*	April–December 1969	October 1970
Surface Air Sampling Program—80th Meridian, *HASL*	January–December 1966	October 1970

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1. Radiation Alert Network July 1970

National Air Pollution Control Administration
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 70 locations distributed throughout the country (figure 1). Due to the density of sampling locations in three respective areas, the Rockville, Md., St Paul Island, and Adak, Alaska, stations were discontinued. Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate National Air Pollution Control Administration officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Data Acquisition and Analysis Branch, Division of Air Quality and Emission, NAPCA, Cincinnati, Ohio. A detailed description of the sampling and analytical procedures was presented in the April 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during July 1970. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting station.

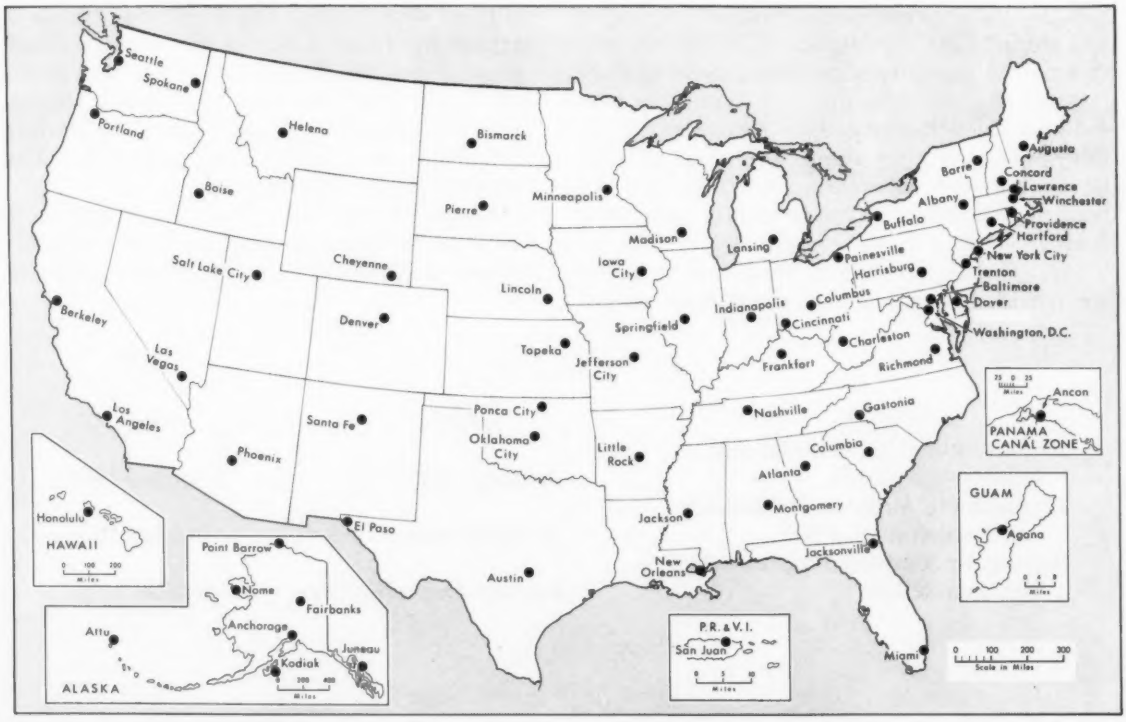

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, July 1970

Station location		Air surveillance				Precipitation				
		Number of samples	Gross beta radioactivity (pCi/m³)			Last profile in RHD&R	Number of samples	Total depth samples (mm)	Field estimation of deposition	
			Maximum	Minimum	Average[a]				Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	22	6	0	2	Oct 70	5	102	5	102	57
Alaska:	Anchorage	5	0	0	0	June 70	[c]				
	Attu Island	17	0	0	0	Nov 70	[c]				
	Fairbanks	21	1	0	1	July 70	10	37	10	37	21
	Juneau	13	5	0	2	Aug 70	8	156	8	156	0
	Kodiak	[b]				Sept 70					
	Nome	[b]				Mar 70	[c]				
	Point Barrow	[b]				Feb 70	[c]				
Ariz:	Phoenix	11	3	1	2	Aug 70	[c]				
Ark:	Little Rock	19	4	0	2	June 70	[c]				
Calif:	Berkeley	23	3	0	0	Sept 70	[c]				
	Los Angeles	23	3	0	1	Mar 70	[c]				
C.Z:	Ancon	18	0	0	0	Sept 70	[c]				
Colo:	Denver	23	9	1	4	Sept 70	3	27	[d]		
Conn:	Hartford	22	2	1	1	July 70	4	19	4	19	6
Del:	Dover	22	2	0	1	May 70	[c]				
D.C:	Washington	22	1	0	0	Feb 70	[c]				
Fla:	Jacksonville	24	4	0	1	June 70	10	171	7	156	50
	Miami	22	0	0	0	July 70	7	73	5	54	0
Ga:	Atlanta	13				Apr 70	[c]				
Guam:	Agana	22	2	1	1	May 70	[c]				
Hawaii:	Honolulu	[b]				Nov 70	2	11	[d]		
Idaho:	Boise	27	1	0	0	Nov 70	1	6	1	6	0
Ill:	Springfield	22	4	1	2	Feb 70	[c]				
Ind:	Indianapolis	8	3	1	2	Apr 70	[c]				
Iowa:	Iowa City	[b]				Sept 70	7	97	7	97	1
Kans:	Topeka	18	7	0	2	June 70	3	25	3	25	3
Ky:	Frankfort	23	7	1	3	Feb 70	[c]				
La:	New Orleans	17	5	1	2	Aug 70	9	138	[d]		
Maine:	Augusta	21	1	0	1	Mar 70	4	40	4	40	0
Md:	Baltimore	21	3	1	2	July 70	6	49	6	49	2
Mass:	Lawrence	22	2	0	1	Sept 70	4	56	4	56	6
	Winchester	22	2	0	1	Oct 70	3	37	3	37	0
Mich:	Lansing	21	3	0	1	Nov 70	11	86	11	86	10
Minn:	Minneapolis	20	3	0	2	May 70	8	139	8	139	25
Miss:	Jackson	23	3	0	1	Aug 70	4	114	4	114	9
Mo:	Jefferson City	19	2	0	2	Apr 70	3	33	3	33	1
Mont:	Helena	22	5	1	1	Oct 70	4	15	4	15	1
Nebr:	Lincoln	21	5	1	3	Apr 70	3	109	3	109	45
Nev:	Las Vegas	16	8	0	2	July 70	[c]				
N.H:	Concord	22	2	1	1	Feb 70	[c]				
N.J:	Trenton	[b]				Aug 70	6	25	6	25	2
N. Mex:	Santa Fe	22	2	0	1	Oct 70	10	95	10	95	4
N.Y:	Albany	17	2	0	1	Apr 70	5	48	5	48	22
	Buffalo	11	2	0	1	Sept 70	[c]				
	New York City	20	2	0	1	Oct 70	[c]				
N.C:	Gastonia	[b]				Sept 70	4	48	[d]		
N. Dak:	Bismarck	17	7	1	3	Feb 70	5	46	5	46	7
Ohio:	Cincinnati	22	5	1	2	May 70	[c]				
	Columbus	[b]				Aug 70	[c]				
	Painesville	[b]				July 70	8	118	8	118	66
Okla:	Oklahoma City	22	4	0	2	Nov 70	1	11	1	11	2
	Ponca City	22	4	1	2	July 70	5	41	5	41	1
Oreg:	Portland	22	6	1	3	Apr 70	1	2	1	2	0
Pa:	Harrisburg	23	2	0	1	Apr 70	1	19	1	19	4
P.R:	San Juan	13	1	0	1	Aug 70	[c]				
R.I:	Providence	[b]				Nov 70	2	10	2	10	1
S.C:	Columbia	23	2	0	1	Oct 70	4	130	2	90	3
S. Dak:	Pierre	19	3	0	1	Aug 70	[c]				
Tenn:	Nashville	8	6	2	4	Nov 70	5	45	5	45	0
Tex:	Austin	21	3	1	1	May 70	1	5	[d]		
	El Paso	21	11	2	5	Feb 70	[c]				
Utah:	Salt Lake City	[b]				Mar 70	5	24	5	24	1
Vt:	Barre	16	3	0	1	June 70	6	52	6	52	7
Va:	Richmond	16	5	0	2	June 70	10	172	10	172	42
Wash:	Seattle	23	2	0	1	June 70	2	16	[d]		
	Spokane	21	1	0	0	June 70	[c]				
W. Va:	Charleston	21	2	1	1	May 70	10	128	10	128	19
Wisc:	Madison	21	2	0	1	Oct 70	6	64	6	64	10
Wyo:	Cheyenne	22	3	1	1	June 70	2	20	2	20	50
		23	8	1	3	July 70					
Network summary		1,153	11	0	2		218	72	5	63	13

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] No report received. (Air samples received without field estimate data are not considered by the data program.)
[c] No precipitation sample collected.
[d] This station is part of the plutonium in precipitation network. No gross beta measurements are done.

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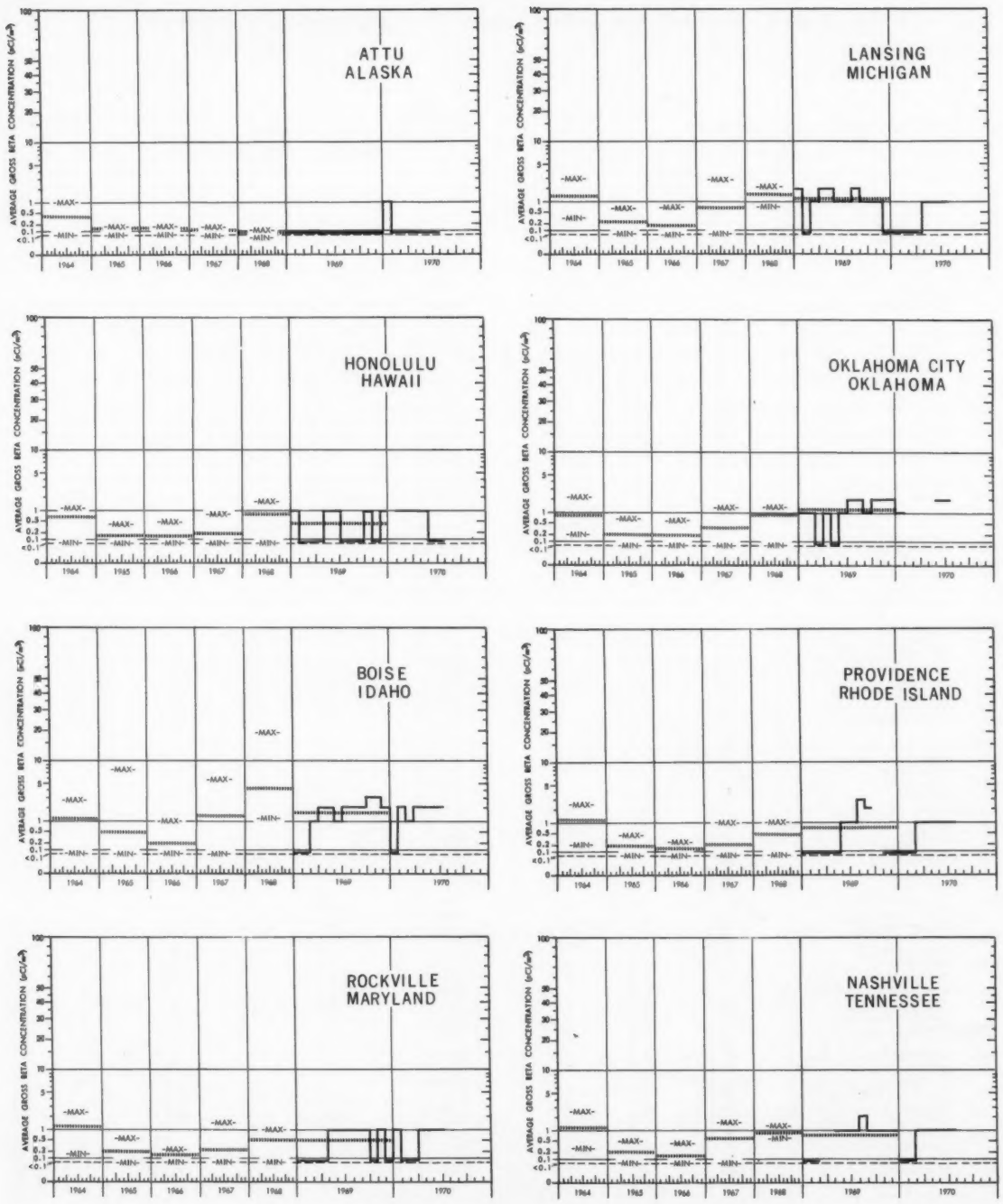

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1964—July 1970

2. Canadian Air and Precipitation Monitoring Program,[1] July 1970

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for July 1970 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, July 1970

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	24	1.3	0.2	0.6	NS	NS
Coral Harbour	31	.3	.0	.1	83	4.3
Edmonton	31	.7	.1	.4	142	15.6
Ft. Churchill	31	.6	.1	.2	161	4.9
Fredericton	12	.6	.2	.3	48	8.4
Goose Bay	18	.6	.1	.3	NS	NS
Halifax	7	.3	.1	.2	57	5.2
Inuvik	6	.4	.1	.3	121	3.4
Montreal	31	.7	.2	.4	105	5.7
Moosonee	6	.3	.0	.2	147	6.1
Ottawa	31	.6	.1	.4	46	4.3
Quebec	30	.6	.1	.4	111	13.3
Regina	6	.5	.1	.3	188	4.9
Resolute	11	.3	.0	.1	31	.5
St. John's, Nfld.	13	.4	.0	.3	87	3.0
Saskatoon	6	.5	.1	.3	265	8.3
Sault Ste. Marie	6	.5	.1	.3	106	11.4
Thunder Bay	31	1.1	.1	.4	139	12.7
Toronto	29	.7	.2	.4	25	2.1
Vancouver	3	.2	.1	.1	113	3.8
Whitehorse	31	.5	.0	.2	215	2.2
Windsor	31	.5	.1	.3	89	9.5
Winnipeg	NS				38	2.6
Yellowknife	31	.6	.1	.3	233	8.2
Network summary	456	1.3	0.0	0.3	116	6.4

NS, no sample

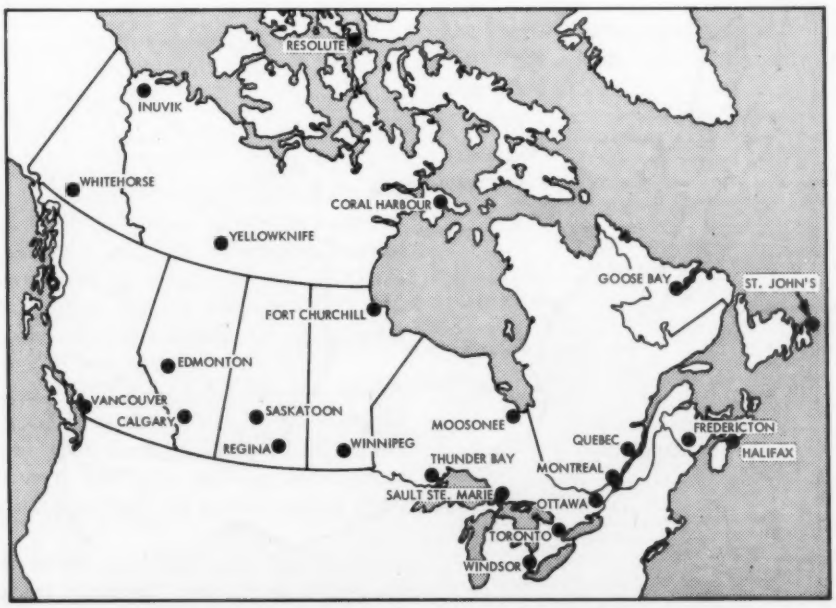

Figure 3. Canadian air and precipitation sampling stations

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3. Mexican Air Monitoring Program July 1970

National Commission of Nuclear Energy
México, D.F.

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the División of Radiological Protection was restructured and its name changed to Direccion General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F.; Mérida; Veracruz; San Luis Potosí; and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Prevision del Golfo de Mexico, the Chemistry Department of the University of Mérida, the Institute de Zonas Desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air through a high-efficiency 6 by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day using high volume samplers.

After each 20-hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta radioactivity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron daughters. The data are not extrapolated to the time of collection. Statistically, it has been found that a minimum of five samples per month was needed to get a reliable average radioactivity at each station (*6*).

The maximum, minimum, and average beta radioactivity in surface air during July 1970 is presented in table 3.

Figure 4. Mexican air sampling locations

Table 3. Mexican gross beta radioactivity of airborne particulates, July 1970

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Acapulco	5	0.07	0.04	0.05
Chihuahua	15	.81	.18	.40
Ciudad Juarez	6	.65	.10	.29
Ensenada	NS			
Guadalajara	NS			
Guaymas	NS			
La Paz	NS			
Matamoros	NS			
Mazatlán	NS			
Mérida	12	.52	.19	.35
México, D. F.	7	.24	.04	.09
Nuevo Laredo	NS			
San Luis Potosí	NS			
Tampico	NS			
Torreón	16	.77	.24	.48
Veracruz	3	—	—	—

NS, no sample, station temporarily shutdown.

Figure 5. Pan American Air Sampling Program stations

4. Pan American Air Sampling Program July 1970

Pan American Health Organization and *U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the January 1968 issue of *Radiological Health Data and Reports*. The July 1970 air monitoring results from the participating countries are given in table 4.

The higher levels of activity in La Paz, Bolivia; Guayaquil, Ecuador, and Lima, Peru, are attributed to the recent French nuclear tests in the Pacific. Gamma analyses of the filters indicate that the activity is due primarily to barium-lanthanum-140.

Table 4. Summary of gross beta radioactivity in Pan American surface air, July 1970

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	7	0.07	0.01	0.04
Bolivia:	La Paz	20	10.39	.34	2.18
Chile:	Santiago	30	2.02	.03	.67
Colombia:	Bogota	23	.24	.01	.09
Ecuador:	Cuenca	NS	NS	NS	NS
	Guayaquil	20	14.06	.19	1.59
	Quito	NS	NS	NS	NS
Guyana:	Georgetown	10	.39	.07	.16
Jamaica:	Kingston	NS	NS	NS	NS
Peru:	Lima	25	23.82	.12	3.99
Venezuela:	Caracas	18	.37	.02	.16
West Indies:	Trinidad	NS	NS	NS	NS
Pan American summary		153	23.82	0.01	1.32

[a] The monthly average is caculated by weighting the individual sample with length of sampling period. Reported values of less than 0.005 pCi/m³ are considered as 0.00 pCi/m³ in averaging.
NS, no sample.

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SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for Lawrence Radiation Laboratory and Shippingport Atomic Power Station.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Lawrence Radiation Laboratory July–December 1969[2]

University of California
Berekeley, Calif.

Berkeley site

The Berkeley site of the Lawrence Radiation Laboratory (LRL) is situated on the western slope of the range of hills running along the eastern side of San Francisco Bay. The laboratory area is largely separate from the main campus of the University, although there is some overlap (figure 1).

To the north and south of the laboratory area are residential areas of the cities of Berkeley and

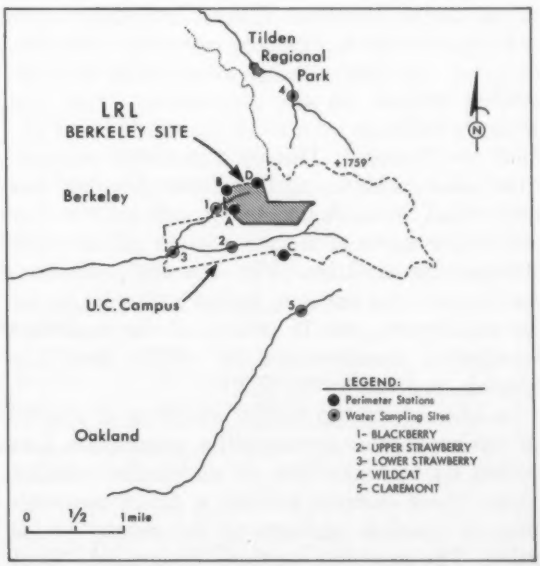

Figure 1. Environmental sampling locations at the Berkeley Site, Lawrence Radiation Laboratory

[2] Summarized from "Results of Environmental Radioactivity Sampling Program, July–December 1969," Lawrence Radiation Laboratory, Livermore and Berkeley, Calif.

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Oakland. The Berkeley campus of the University of California is on the west; to the east are the Lawrence Hall of Science and the Space Sciences Laboratory; beyond them lies uninhabited watershed land and the Tilden Regional Park.

The most prevalent wind direction is westerly. During the summer months the afternoon sea breeze establishes a very pronounced prevailing westerly wind direction. At other times, the direction is less predictable. Annual rainfall is 23 inches, almost all of which falls between November 1 and May 1. The prevailing wind direction during precipitation is southerly.

The laboratory carries on a wide ranging program of general research in the fields of both physical and biological sciences. Facilities include a number of large accelerators and various physics, chemistry, biology and medical research laboratories.

The basic policy at LRL has long been to prevent, as far as possible, any release of radioactive material to the environment, no matter how small. No deliberate releases are sanctioned, except where no practical method for containment has yet been developed and quantities are small compared with standards established by the ICRP and AEC.

The most sensitive measurements of releases are those taken closest to the source itself, before dilution makes detection of small quantities more difficult. The stack sampling program, therefore, provides the most useful information for controlling releases to the atmosphere. Over 100 separate exhausts from hoods and glove-box manifolds are sampled. The total quantity released from these stacks during July–December 1969 was 130 nCi of alpha radioactivity, 360 mCi of carbon-14, 19 curies of tritium and 65 μCi of other beta-particle emitters. The average concentration in the total exhaust, before any dilution by the atmosphere, was 15 percent of the maximum permissible concentration for offsite breathing zone air, as given by the ICRP.

In addition to the careful sampling of stacks, an environmental air sampling program is also carried on to make sure no undetected releases occur. These samples provide a direct measurement of possible exposure to the nearby population. The sampling stations designated "local area" are scattered around the site and provide samples of the atmosphere on the site itself. The "perimeter" samples are taken at the boundary line of University property, in the direction of populated areas. From the results of these samples, it is apparent that there has been no significant exposure from radioactive materials released by LRL. The levels of radioactivity observed in each type of sample are presented in table 1.

Table 1. Atmospheric monitoring, LRL Berkeley site July–December 1969

Sampling locations (number of locations)	Number of samples	Average concentration (pCi/m³)			
		Alpha radioactivity		Beta radioactivity	
		Average	Maximum	Average	Maximum
Local area (10)	263	0.000	0.006	0.20	0.65
Perimeter (4)	105	.001	.006	.20	.95

Rain or dry fallout is also collected at each of these environmental stations. Open 15-inch diameter polyethylene bags form the collecting vessel. If no rain has fallen, the bags are rinsed out with dilute nitric acid to obtain a sample. Since on the average, the more remote perimeter stations show about the same radioactivity as the nearer ones, the radioactivity does not result from laboratory operations. The radioactivity levels in samples collected at each location are summarized in table 2.

Table 2. Total deposition, LRL Berkeley site July–December 1969

Sampling locations (number of locations)	Number of samples	Average deposition (nCi/m²)			
		Alpha radioactivity		Beta radioactivity	
		Average	Maximum	Average	Maximum
Local area (10)	51	0.03	0.11	3.19	4.36
Perimeter (4)	22	.07	.10	3.03	4.54

All liquid waste known to be radioactive is collected, solidified, and shipped away. Other liquid wastes are discharged directly to the municipal sewer system. Small quantities of radioisotopes now and then are accidentally released to the sewer system. There are two outfalls, each of which is monitored by a continuous proportional sampling system to insure that no significant quantities have been discharged. The total concentration (alpha-plus-beta radioactivity) in sewage is only 15 percent of the standard for drinking

water and therefore does not constitute an exposure threat. A sizeable fraction of the measured beta concentration is the naturally occurring isotope potassium-40 from human wastes and chemicals.

The storm drainage from the laboratory flows into the surface stream system. These surface streams are exposed as they run through the University property and are sampled at three places. Results are listed as "onsite streams" in table 3. Two nearby offsite streams are also sampled to provide a comparison. All concentrations are safely below the standard for drinking water. The results from the water sampling program are presented in table 3.

Table 3. Water monitoring, LRL Berkeley site July–December 1969

Type and source of sample	Number of samples	Concentration (pCi/liter)			
		Alpha radioactivity		Beta radioactivity	
		Average	Maximum	Average	Maximum
Surface water:					
Onsite streams:					
Blackberry	27	0.23	1.3	3.84	21.5
Lower Strawberry	27	.90	8.1	11.71	54.6
Upper Strawberry	27	.44	3.6	4.31	15.8
Summary	81	.52		6.62	
Offsite streams:					
Claremont	27	.58	6.6	3.18	19.1
Wildcat	27	.38	2.2	3.38	9.1
Summary	54	.48		3.28	
Tap water	51	.023	.18	1.20	2.3

Neutron and gamma-ray fields are measured at each of the four perimeter stations as well as at several locations within the site. Background measurements are obtained from a leased building used as a low-level counting room in downtown Berkeley. This building is remote from the main LRL site and measurements are not influenced by accelerator operations.

At each station, gamma measurements are made by a recording G-M detector, standardized with a calibrated radium source. These instruments operate unattended, and each can operate for 1 week on its internal battery, should external power fail.

Several neutron detectors are employed at each station. The primary detector is a BF_3 gas proportional counter in a 2 1/2 inch-thick paraffin-lined moderator. This detector is sensitive in the region from 0.1 to 20 MeV, where 75 percent of the biologically significant neutrons exist. A polyethylene-lined proton recoil neutron detector provides a measure of the energy flux density. The ratio of energy flux density to neutron flux density gives the average neutron energy which allows conversion of the data to dose in rems. Cobalt disks in moderators are maintained as long term integrating neutron monitors at many sites throughout the laboratory as well as at each perimeter station.

Cosmic ray intensity is continuously monitored by a meson detector with an effective angle of acceptance of 2.3 steradians (in the upward direction). This provides information on the background neutron levels contributed by cosmic rays.

At each station, total radiation levels are well below the standards set for the general public by the ICRP and NCRP. Levels are somewhat higher than they were during the first 6 months of 1969. Results are presented in table 4.

Livermore site

The Livermore site of LRL (figure 2) is located in the Livermore Valley midway between the Pacific coast and the San Joaquin Valley in northern California, approximately 50 miles southeast of San Francisco. Shielded from the ocean

Table 4. Beta-gamma and fast neutron surveillance results, Berkeley site, January–December 1969

Station	Total beta-gamma exposure (mrem) (background subtracted)		Total fast neutron exposure[a] (mrem) (background subtracted)	
	January–June 1969	July–December 1969	January–June 1969	July–December 1969
A	10.9	14.3	38.89	226.6
B	4.4	8.7	26.42	77.3
C	[b]	[c]	[b]	.31
D	6.1	5.1	55.67	39.9
Shattuck Ave. and Berkeley Way	[c]	[c]	[b]	[b]

[a] 2.45×10^7 n/cm² = 1 rem.
[b] Background.
[c] Detector not in service.

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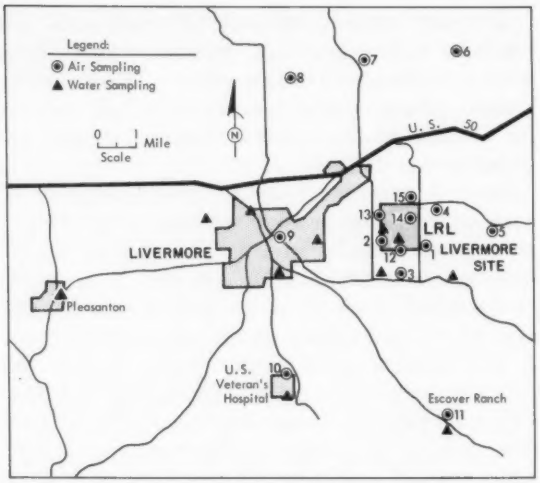

Figure 2. Environmental sampling locations at the Livermore Site, LRL

by the western hills, the Livermore Valley has a warm, dry climate. Annual rainfall is about 14 inches and the relative humidity is about 30 percent during the summer months and about 40–50 percent the remainder of the year. Prevailing winds are from the west, but inversions are frequent during the night.

Agriculture is the principal activity in the Livermore Valley. Roses, grain, hay, and grapes are the major products. Several cattle and sheep ranches surround the Livermore site.

The Livermore site comprises an area of 1-square mile, approximately 3 miles east of the city of Livermore. Livermore and Pleasanton, with a combined population of 45,000, are populated areas of primary interest to the Livermore site.

An environmental sampling program is maintained to provide information regarding the effectiveness of control measures and to determine whether any radiological changes in the environment are the result of laboratory operations. The sampling program includes air particulates, soil, domestic water, sewer effluent, sewage plant products, milk, and vegetation. The milk samples are obtained from one dairy in the Livermore Valley and from another dairy near Site 300. Air and soil samples are collected to ascertain that control efforts are restricting the release of radioactivity from the laboratory to levels which do not exceed the permissible levels for the neighborhood around an atomic energy facility. The water samples are collected to ascertain that radioactivity is not entering the underground water supply which provides most of the domestic water for the cities of Livermore and Pleasanton and is the sole supply for ranches in the Livermore and Amador Valleys. Samples were taken at the Livermore Sewage Disposal Plant to establish that liquid effluent from the laboratory is not contributing significant radioactivity to the dried sludge or liquid effluent produced. The dried sludge is used as an agricultural soil conditioner. Some liquid effluent released to the Los Positas Arroyo is used for irrigation of the golf course turf and some agricultural land.

Air samples are collected continuously at 15 sites within 5 miles of the laboratory. Samples are collected at a rate of 4 cfm on 100 cm^2 HV-70 filter papers, which are changed after every 7 days of operation. A minimum decay period of 96 hours is observed before the samples are counted to eliminate the effect of natural radon and thoron daughters. At no time was any detectable alpha radioactivity observed on the air filters. The average airborne beta radioactivity of 0.1 pCi/m^3 was about the same as that reported during the previous 6 months. The beta radioactivities were below the AEC radiation protection standard of 1 pCi/m^3.

The measurement of low level "background" radiation during this period was accomplished with thermoluminescent dosimeters located at nine points on the site perimeter and at three offsite locations. The exposures are reported as the difference between the TLD reading and normal background for this area. Differences of 10 mR or less are not considered significant and are reported as <10 mR. The three offsite locations recorded no exposures attributable to Livermore operations. At three of the nine locations in the controlled area, exposures of 17 to 29 mR were recorded (table 5).

Domestic water samples were collected monthly from ten nearby sources. No sample showed an alpha specific radioactivity above the limit of detection (5.0 pCi/liter). The beta radioactivity fluctuated from the limit of detection (1.8 pCi/liter) to 10 pCi/liter. The average beta radioactivity concentration was 2.2 pCi/liter. The average alpha and beta radioactivity concentrations were below the AEC standard of comparison of 30 pCi/liter.

Table 5. External gamma radiation measurements, LRL Livermore site, July–December 1969

Dosimeter location[a]	Exposure[b] (mR)
1	< 10
2	< 10
3	< 10
4	29
5	< 10
6	26
7	< 10
8	17
9	< 10
10	< 10
11	< 10
12	< 10

[a] Locations 1–3—uncontrolled area.
Locations 4–12—controlled area perimeter.
[b] The figures in this column are the difference between the TLD badge and normal background. Exposure differences of 10 mR or less are reported as < 10 mR.

The tritium radioactivity of water samples ranged from the limit of detection (5 nCi/liter) to a high value of 5.5 nCi/liter.

Samples were collected daily at the laboratory sewer discharge. The average alpha radioactivity concentration in the sewer effluent ranged between 9 and 38 pCi/liter while the monthly average beta radioactivity varied between 170 and 780 pCi/liter. The AEC standard is 400 pCi/liter. The average tritium content of the effluent was 77 nCi/liter with a maximum of 5,700 nCi/liter. The AEC standard is 100 mCi/liter. The effluent was analyzed for strontium-90 and radium-226-228 radioactivities. The average monthly radioactivity of strontium-90 ranged from 5.7–20 pCi/liter; radium-226–228 ranged from 2.5 to 7.6 pCi/liter.

Samples of top layer soil are collected quarterly at the 19 sampling stations surrounding the Livermore site. The alpha radioactivity of each sample was less than the limit of detection (1.5 pCi/g). The beta radioactivity fluctuated from the limit of detection (3.5 pCi/g) to 17.2 pCi/g, averaging 6.6 pCi/g. The concentrations detected are within the normal range for soil in the Livermore Valley, as determined from surveillance during previous years.

Average radioactivity levels in monthly milk samples amounted to 1.7 pCi/liter of cesium-137 and 3.6 pCi/liter of cerium-141–144, for the two dairies. The average tritium concentration in milk was at or below the limit of detection (5 nCi/liter). Vegetation samples were collected during September and December of 1969. The radioactivity of 15 unwashed grass samples and four eucalyptus leaves samples is presented in table 6. A portion of each sample was freeze dried, and the water collected was analyzed for HTO.

Continuous radioactive air sampling is maintained on the effluent from stacks of operations that are potential sources of radioactive material releases. These facilities include the hot cells, transuranic chemistry, plutonium metallurgy, critical assembly cells, and the reactor building.

The effluent from these buildings passes through absolute filters prior to being exhausted to the atmosphere. The limit of sensitivity for the stack monitoring systems is generally 0.1 pCi/m^3 or less. The permissible offsite concentrations were not exceeded as a result of stack effluent during the past 6 months.

Site 300

The high-explosive test area at Site 300 (figure 3) covers 10-square miles in the hills in a very sparsely populated ranching area about 15 miles southeast of Livermore and 8 miles southwest of

Table 6. Radioactivity in vegetation, LRL Livermore site July–December 1969

Nuclide	Concentration (pCi/g dry weight)[a]				Limit of detection
	Grass		Eucalyptus leaves		
	Average	Maximum	Average	Maximum	
Beryllium-7	0.72	2.40	0.07	0.24	0.01
Manganese-54	.03	.05	.01	.02	.01
Zirconium-95	.38	.66	.13	.23	.01
Ruthenium-103,-106	.32	1.02	.17	.18	.02
Antimony-125	.02	.07	.02	.05	.02
Cesium-137	.01	.11	.01	.01	.01
Cerium-141,-144	1.05	2.23	.28	.51	.02
Tritium	23	130	10	25	5

[a] Except tritium which is nCi/liter of water.

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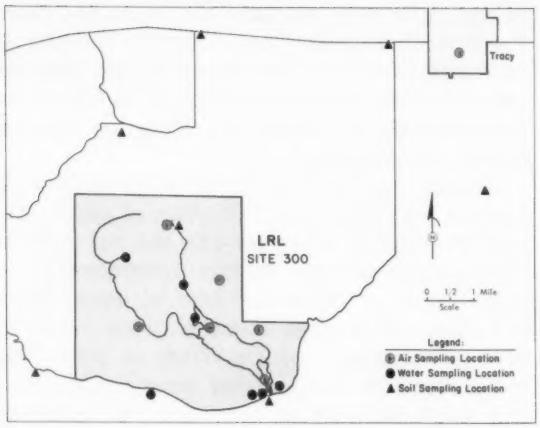

Figure 3. Sampling locations at Site 300, LRL

Tracy. The chief area of concern for Site 300 is Tracy. The population there is about 15,000. Air and water samples are taken to determine whether operations at Site 300 are changing the normal radioactivity levels in the vicinity. The 10 air samplers at Site 300 are operated at about 50 cfm on a continuous basis with the filter papers being changed on regular schedule. Most of these air samplers are located within the boundaries of the test site due to unavailability of electric power facilities offsite (table 7). Water samples are taken from onsite wells because they are the only readily accessible sources of underground water. Streams in the area are sampled when they contain water. No sample showed an alpha radioactivity concentration above the limit of detection (5.0 pCi/liter). The beta concentration ranged from the limit of detection (1.8 pCi/liter) to 12 pCi/liter, averaging 4.5 pCi/liter. The average tritium concentration was at or below the detectable level of 5 nCi/liter.

Soil samples are collected quarterly at nine offsite locations. The alpha radioactivity of each sample was 1.5 pCi/g, the limit of detection. The beta radioactivity ranged from the limit of detection (3.5 pCi/g) to 17 pCi/g, with an average activity of 9.2 pCi/g.

None of the average concentrations of air, water, and soil samples exceeded the standards of comparison applicable to activities at the test site, nor did any of the results increase significantly compared to 1968 data. Therefore, it appears that radiological control measures at Site 300 were adequate and that no significant radioactivity was released to the environment near the site during this period.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–December 1968	October 1969
January–June 1969	April 1970

Table 7. Airborne particulate radioactivity, LRL Site 300 July–December 1969

Sampling location	Number of samples	Alpha radioactivity[a] (fCi/m³)		Beta radioactivity[a] (fCi/m³)	
		Average	Maximum	Average	Maximum
1	38	<0.2	<0.2	132	460
2	39	< .2	1.2	185	830
3	36	< .2	< .2	205	1,050
4	37	< .2	< .2	151	483
5	39	< .2	< .2	146	584
6	30	< .2	1.9	124	469
7	38	<1.0	<1.0	148	472
8	34	< .2	< .2	187	613
9	34	< .2	< .2	156	413
10	36	< .2	< .2	160	419
Summary				159	

[a] Limit of detection—Alpha radioactivity—location 1–6, 8–10, 0.2 fCi/m³.
location 7, 1.0 fCi/m³.
beta radioactivity —location 1–6, 8–10, 2 fCi/m³.
location 7, 10 fCi/m³.
Variations in limits of detection result from differing flow rates. Estimated error limits—alpha radioactivity, ± 30 percent; beta radioactivity, ± 20 percent.

2. Shippingport Atomic Power Station January–December 1969[3]

Duquesne Light Company
Shippingport, Pa.

The Shippingport Atomic Power Station is located on the south bank of the Ohio River in a site consisting of over 400 acres. The site is about 25 miles northwest of Pittsburgh and about 11 miles below the confluence of the Beaver and Ohio Rivers (figure 4). The station is designed to produce electric energy by a conventional central station type turbine-generator unit. The pressurized water reactor consists of a closed system in which water is circulated by pumps over an array of nuclear fuel elements, or core, contained in a reactor vessel, to heat exchangers where steam is formed in a separate isolated system.

Radioactive waste handled under the environmental program includes liquid and gaseous effluents released into the Ohio River and atmosphere, respectively. The levels of radioactivity released were below Shippingport discharge limits. These limits are based upon radiation standards set forth by AEC's division of Operational Safety in directives published in the AEC Manual[1] and a waste discharge permit from the Pennsylvania Sanitary Water Board.

[3] Summarized from "Environmental Radioactivity at the Shippingport Atomic Power Station for the Calendar Year 1969."

Ohio River water analysis

During 1969, weekly composite samples were obtained from two continuous automatic samplers in the station circulating water line upstream and downstream from the radioactive water effluent. Both suspended and dissolved materials in the composite samples were analyzed for gross alpha and beta radioactivity. Each composite is also analyzed for potassium-40 content. No significant difference was observed among the average alpha, beta, and potassium-40 radioactivity for the influent samples. The results of these analyses are presented in table 8.

Ohio River sediment analysis

Once during each calendar quarter, sediment samples from the Ohio River were collected upstream and downstream from the circulating water outfall with a Birge-Ekman dredge. These samples were quantitated assuming all detected radioactivity to be cobalt-60, which is the major constituent of radioactive contamination at the sta-

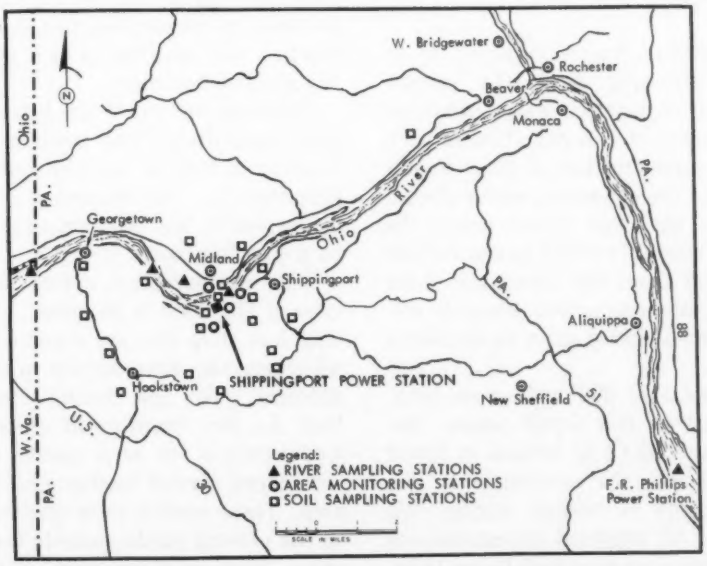

Figure 4. Shippingport Power Station sampling locations

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Table 8. Gross radioactivity in the Ohio River, Shippingport Atomic Power Station, January–December 1969

Type of radioactive material	Average concentration (pCi/liter)							
	Influent samples				Effluent samples			
	Jan–March	April–June	July–Sept	Oct–Dec	Jan–March	April–June	July–Sept	Oct–Dec
Alpha:								
Total solids	0.61	0.67	1.17	1.90	0.60	9.70	1.23	1.47
Beta:								
Total solids	8.60	12.00	15.00	14.80	9.00	14.00	12.80	16.40
Potassium-40	3.2	4.2	6.0	8.8	3.1	4.3	6.1	8.8

tion. The results of the sediment samples are presented in table 9. These data indicate that there was no increase of radioactivity in the river sediment as a result of the station's discharges.

Table 9. Total radioactivity in the Ohio River sediment samples, Shippingport, January–December 1969

1969	Number of samples	Gross radioactivity (pCi/g)	
		Upstream	Downstream
January–March	2	7.50	8.90
April–June	2	9.10	7.80
July–September	2	6.49	7.07
October–December	2	9.25	9.81

Liquid radioactive waste

The liquid radioactive wastes disposed of at Shippingport are primarily from the reactor coolant system. The radioactive waste produced by the plant is reduced in concentration in such a manner that the concentration of these wastes in water measured at the condenser water stream before discharge to the Ohio River meets the limits as delineated above. In order to assure that the liquid discharged from the plant will meet specified tolerances, all radioactive waste is collected, processed, and sampled prior to discharge to the environment.

During 1969, a total of 208 mCi gross beta-gamma radioactivity in the liquid waste (exclusive of tritium) and 20 Ci of tritium in liquid waste were released into the environment. The average daily discharge of tritium during this period was 55 mCi. All reported concentrations released to the environment were well below those specified by State and Federal regulations.

Gaseous radioactive waste

Gaseous discharges to the atmosphere, identified as xenon-133, are controlled and released at concentrations less than the AEC standard of 300 nCi/m^3. During the year 1969, a total of 75.0 microcuries of xenon-133 were released from the plant site at less than the specified concentration.

Film badge monitoring

Twelve film badges for detecting beta-gamma radioactivity were posted continuously at the site perimeter in an attempt to determine the external radiation exposure in the immediate area. In order to accomplish this, a control film badge location was established at a point 10 miles from the station boundary.

The construction of the Beaver Valley Nuclear Unit necessitated the permanent change in the location of four of the environmental monitoring film stations. The frequency of film change and development has been changed from a quarterly to a monthly basis.

Since the minimum detectable exposure of the type of film used is 25 mrem, all film which indicate less than this are reported as "0" mrem. In all cases, the film density was not measurably different from the control film. This indicates that the film exposure at all locations averaged 0.03 mrem/h for each month of 1969 which is considered normal background radiation for this area. These results show that radiation exposure to the general public outside the station was not above that received from natural background radiation levels.

Fallout

Precipitation and fallout are collected in high-walled pot at one location on the site and analyzed monthly for gross alpha and beta radioactivity. A summary of the quarterly average fallout results for 1969 is presented in table 10.

Table 10. Radioactivity in fallout, Shippingport January–December 1969

1969	Deposition rate (nCi/m²/month)	
	Alpha radioactivity	Beta radioactivity
January–March	0.13	2.84
April–June	.20	13.88
July–September	.27	4.00
October–December	.18	17.40
Yearly average	0.20	9.52

Conclusion

From the data presented above, it may be concluded that, during 1969, the radioactive effluent releases from the Shippingport station site did not cause any significant increase in background radiation levels. In this regard, the station procedures relative to controlling radioactive discharges to the environment are considered to be effective in protecting the health and safety of the general public.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–December 1968	October 1969

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Reported Nuclear Detonations, October 1970

(Includes seismic signals from foreign test areas)

The U.S. Atomic Energy Commission (AEC) announced only one United States nuclear test for October 1970. A nuclear test in the yield range between 20 and 200 kilotons TNT equivalent was conducted underground on October 14, 1970, by the AEC at its Nevada Test Site.

On October 14, 1970 the United States recorded seismic signals, presumably from a Soviet underground nuclear explosion. The signals originated at approximately 0200 e.d.t., at the Novaya Zemlya nuclear test area and were equivalent to those of an underground nuclear explosion with a yield of about 6 megatons. This is the largest such event detected in this area.

The AEC also announced that Communist China set off a nuclear explosion in the atmosphere at approximately 0330 e.d.t., October 14, 1970, at their Lop Nor nuclear test area. The yield was about 3 megatons. This is the first Chinese test announced this year.

Not all of the nuclear detonations in the United States are announced immediately, therefore, the information in this section may not be complete. A complete list of announced U. S. nuclear detonations may be obtained upon request from the Division of Public Information, U. S. Atomic Energy Commission, Washington, D. C. 20545.

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

ANALYSIS OF IODINE-131 DATA IN BOVINE THYROIDS FOR OCTOBER 1964 THROUGH FEBRUARY 1969. *John L. Russell* and *Gerald A. Pliner. Radiological Health Data and Reports, Vol. 11,* November 1970, pp. 573—580.

A detailed analysis of the bovine thyroid data from October 1964 through February 1969, as reported in *RHD&R,* shows that most positive results can be related to various nuclear tests with known atmospheric intrusions. The widespread nature of various samples having positive concentrations of short-lived fission products and the rapid increase of levels in these samples indicate the source to be a major atmospheric intrusion.

Estimates determining thyroid dose in man from iodine-131 concentrations in bovine thyroids appear to be feasible under selected conditions but are of little use in evaluating nationwide network data. The lower limit of detectability is 1 pCi ^{131}I/g bovine thyroid, and most samples at this level have a 2-standard deviation error greater than the measured quantity.

KEYWORDS: Atmospheric intrusions, iodine-131, bovine thyroid, summary, United States.

RESULTS OF 33,911 X-RAY PROTECTION SURVEYS OF FACILITIES WITH MEDICAL OR DENTAL DIAGNOSTIC X-RAY EQUIPMENT, FISCAL YEARS 1961–1968. *Lawrence R. Fess, Richard B. McDowell, Wayne R. Jameson* and *Ray W. Alcox. Radiological Health Data and Reports, Vol. 11,* November 1970, pp. 581-612.

The results of radiation surveys of 33,911 medical and dental x-ray facilities are presented and analyzed. It was found that a high percentage of x-ray machines in medical facilities have improper collimation and inadequate filtration. In addition, a large proportion of the facilities do not possess adequate accessory patient or operator shielding. The use of an open-end aiming device high-speed film, and the need to improve darkroom procedures were the primary recommendations made for dental facilities.

KEYWORDS: Collimation, dental x-ray facilities, diagnostic x-ray equipment, filtration, fluoroscopic machines, healing arts, x-ray medical facilities, radiographic machines, radiation surveys, United States, x ray.

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